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THE UNIVERSITY OF ALBERTA

THE DESIGN OF A CAPACITY REQUIREMENTS PLANNING SYSTEM AND A DECISION SUPPORT SYSTEM FOR STRATEGIC PLANNING

by

© GOPALAKRISHNAN K.N.

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

IN

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DEPARTMENT OF MECHANICAL ENGINEERING

EDMONTON, ALBERTA

FALL 1988

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled THE DESIGN OF A CAPACITY REQUIREMENTS PLANNING SYSTEM AND A DECISION SUPPORT SYSTEM FOR STRATEGIC PLANNING submitted by GOPALAKRISHNAN K.N. in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in MECHANICAL ENGINEERING(ENGINEERING MANAGEMENT).

Supervisors

Date 3 Aug , 1988

ABSTRACT

Manufacturing companies in the eighties are turning more and more towards the use of computer-based production and inventory management systems. These systems provide for a better control of work-in-process inventory, capacity requirements, and order tracking in a manufacturing environment. The advantages of a computerized system is that these systems can respond quickly to any changes in input and compute the revised plan details. These systems also aid in developing reports for upper management, providing for a logical co-ordination of the day-to-day manufacturing activities and for long range planning.

Recent advances in the microcomputer technology have made these systems available and affordable to small manufacturers. In this study, a microcomputer-based capacity requirements planning(CRP) system was designed and partially tested with an actual implementation at Argo Material Handling System Limited. The result to date indicate an improvement in material control and shop planning.

An approach to strategic planning and the benefits of a decision support system(DSS) have been stressed. A simple conceptual model for decision making has been presented.

The computer programs are written in the BASIC language and are easily adaptable to any small company with minor modifications. A concise user's manual is included which explains the various programs in the CRP software package.

ACKNOWLEDGEMENT

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1. INTRODUCTION

1.1 Purpose

The purpose of this two part study is to design the major modules of the capacity requirement planning and costing system for a microcomputer based Integrated Production and Inventory Control System. In addition a Decision Support System(DSS) for Strategic Planning will be outlined. The integrated system when developed will be part of a computerized production and inventory control system that can be used by any company after modifying the modules to suit their specific needs. The system will be tested at a local manufacturing organization.

1.2 Background Information

The total production, inventory control and costing system being developed consists of two major modules, viz., the Material Requirements Planning(MRP) module and the Capacity Requirements Planning(CRP) module. The MRP modules were designed by another graduate student, Stephen Cheng as an M.Sc. thesis[3]. The flow chart for the MRP is shown in Figure 1.1. The CRP receives its input from the MRP and makes an analysis to check if the requirements of the MRP can be successfully achieved. The flow chart for the CRP is shown in Figure 1.2. The combined flow chart for the microcomputer based Integrated Production and Inventory Control System is shown in Figure 1.3. The system will be implemented at Argo Material Handling System Limited., which manufactures a wide variety of material handling equipment. Among the large range of material handling equipment are dock levellers, elevating docks, wheel-chair lifts, and

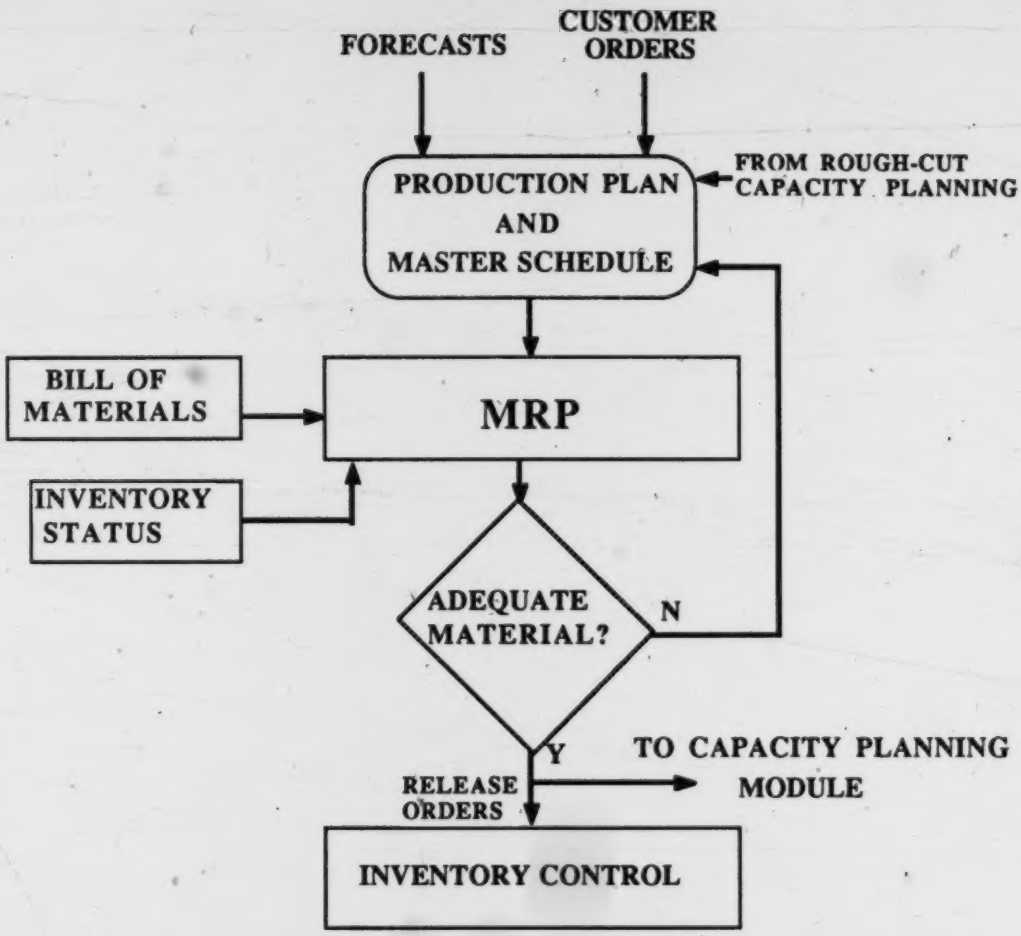


Figure. 1.1. Flow chart for microcomputer based MRP system

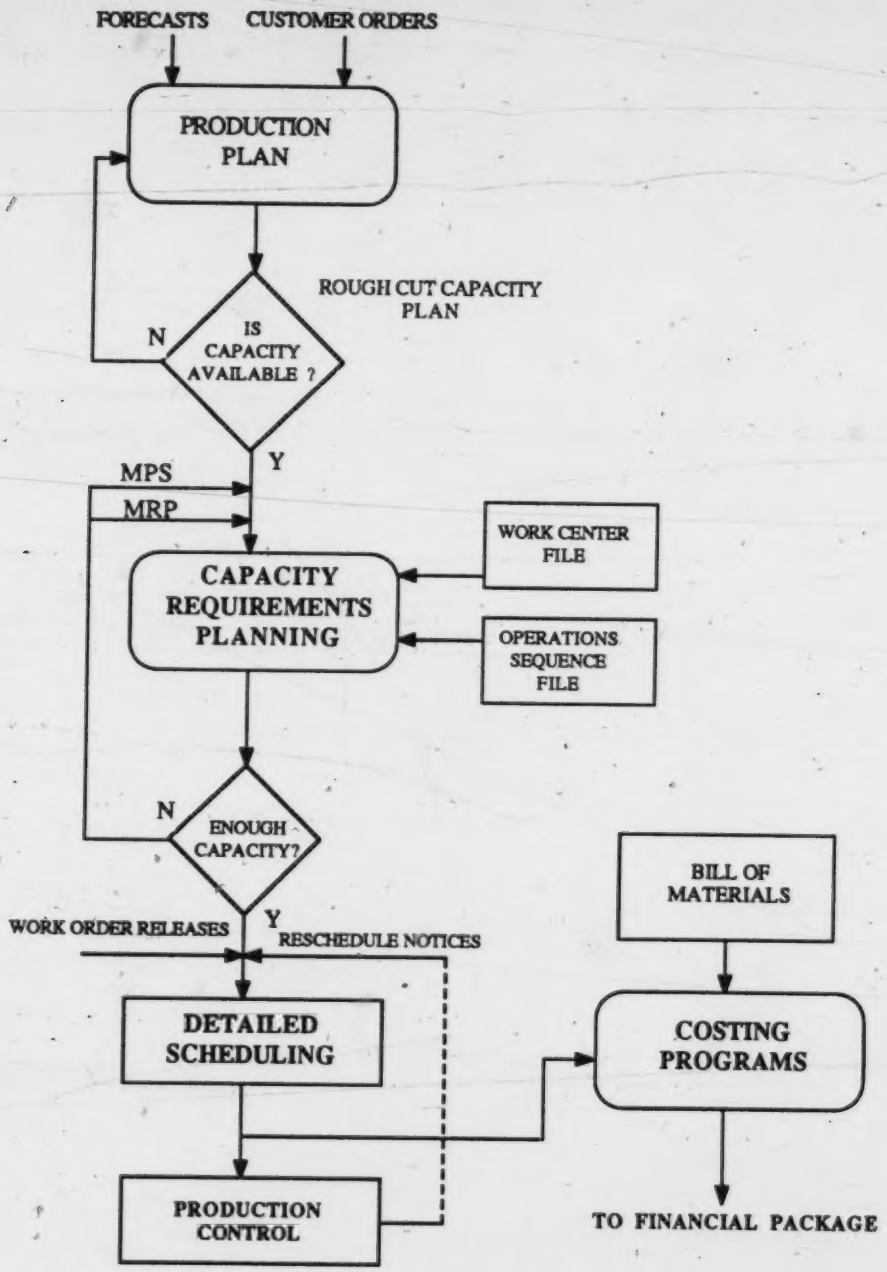


FIGURE 1.2 FLOW CHART FOR MICROCOMPUTER BASED CRP SYSTEM

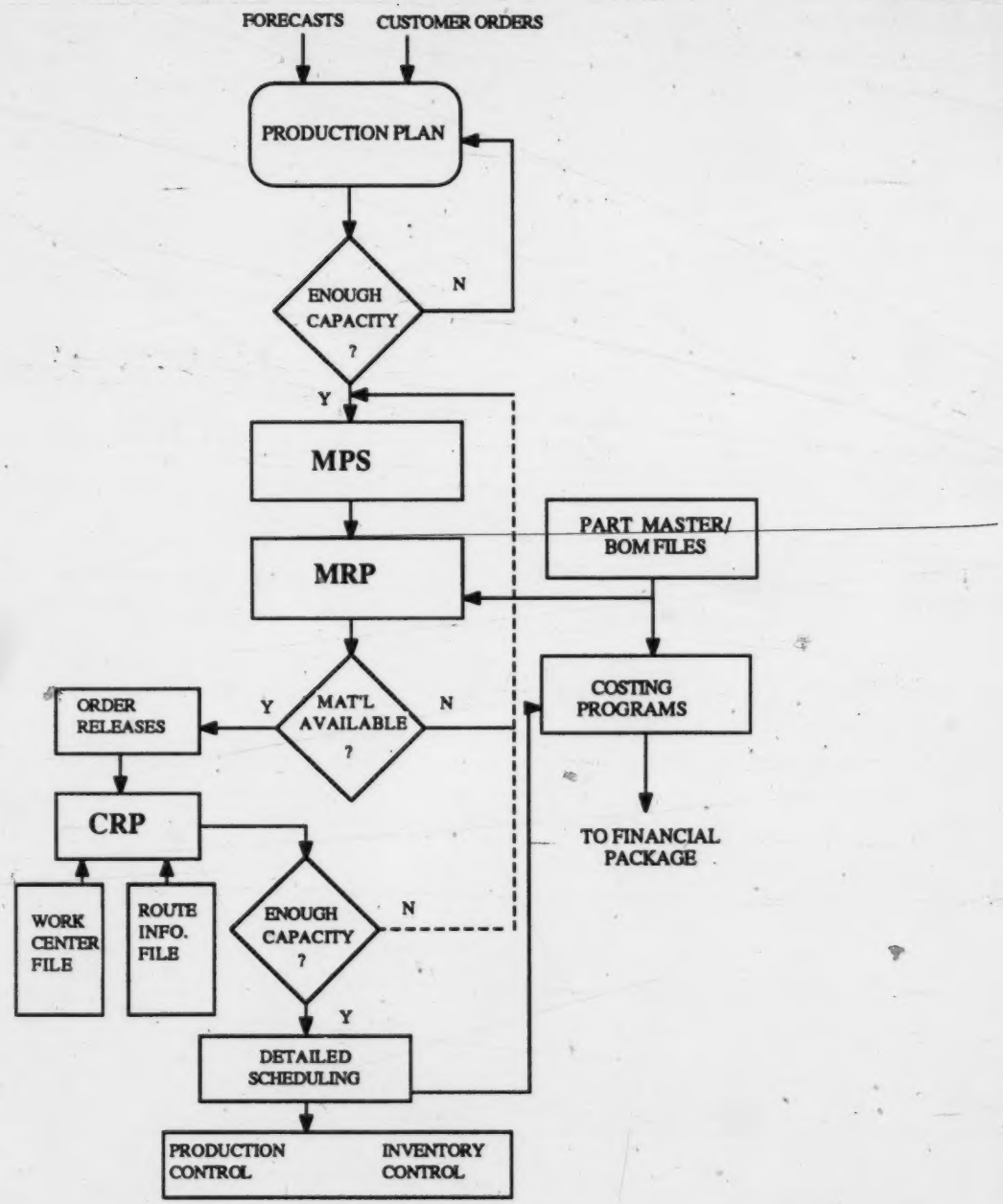


FIGURE 1.3 FLOWCHART FOR AN INTEGRATED PRODUCTION AND INVENTORY CONTROL SYSTEM

dock shelters. Dock levellers and elevating docks account for over 60% of the total sales. The company is based in Edmonton and has manufacturing licensing arrangements with several companies around the world.

At present the company practices an informal form of production, inventory planning and control system. The method is based on a combination of past experience, 'trial and error' and a re-order point system based on sales bookings. Computerizing the system will greatly help in keeping track of the activities done in the shop and also permit management to review the progress made more effectively.

1.3 Scope and Methodology

The scope of this thesis consists of developing a computerized Capacity Requirements Planning System to be executed on a PC, and to discuss the outline of a Decision Support System(DSS) for Strategic Planning. The Capacity Requirements Planning System consists of the following modules:

(i) Capacity planning module.

(ii) Shop order processing module.

(iii) Systems processing module(including costing and managerial reporting).

The capacity requirements planning module takes care of the day-to-day requirements of the shop floor. This module takes information from the MRP matrix and prepares detailed work-orders for the shop and

vendor orders after finding out which items are in stock and which items have to be produced. The systems processing module will use monthly information to find out utilization and prepare cost exception reports. It will also maintain and update cost information of each and every part manufactured. It is this module that maintains the data file information to be interfaced with the financial package.

1.3.1 Master Production Schedule(MPS)

The manufacturing objective of quantity and due date for the final products are transformed by the MPS into a shop plan. The decisions in this phase depend on both forecast and confirmed customer orders. The optimization criteria are: meeting due dates, minimum level of work-in-process, and plant load balance. The MPS uses a rough cut capacity planning method to:

(i) Establish times available at each work center.

(ii) Sequence work from queues.

(iii) Specify end-of-shift routines.

1.3.2 Capacity Requirement Planning

The purpose is to plan the manufacturing and purchasing activities necessary to meet the targets of the MPS. A quantity and due date are set for each part of the final product. Decisions in this phase are confined to the demands of the MPS and the optimization criteria include: meeting due dates, minimum level of inventories, and departmental load balance.

1.3.3 Shop Order Processing

The goal is to transform the manufacturing requirements as set forth in the capacity requirement planning phase into a detailed machine loading plan for each work center in the plant. It is essentially a scheduling and sequencing task. The decisions in this phase are confined to the demands of the requirement planning phase and the optimization criteria include: capacity balance, meeting due dates, minimum level of work-in-process, and manufacturing lead times. The decision variables are plant capacity, tooling, on-hand material and manpower.

1.3.4 Costing

In this phase for each and every part manufactured in the plant an estimate of the cost to make it is made. This information is then passed on to the financial package. The cost details are updated periodically.

1.3.5 Financial Planning

Developing a module for this area is not being done as there are many standard software packages readily available. However, interfacing the costing and sales information with this package is essential for the integrated system to be implemented successfully. The interfacing of the financial package will be undertaken by another graduate student. The financial package will handle regular accounting and financial functions like General Ledger(GL), Accounts Receivable(AR) etc., and the outputs will be financial statements on a periodic basis.

1.3.6 Strategic Planning

One of the objectives of the management of an organization is not only to improve efficiency of current operations but also to plan for the efficient use of the resources in the future. Decisions such as product lines to be added/trimmed in the future, what components may be farmed out, what additional promotion is needed for the product lines if a competitor emerges, and what additional facilities have to be added to achieve the planned growth are required on a continual basis to remain profitable in the long run. This sort of planning approach for future courses of action is generally termed strategic planning.

1.4 Software Considerations

The CRP system software has been developed on the IBM Personal Computer using the programming language BASIC[1][7][18] (Beginner's All-purpose Symbolic Instruction Code). Although BASIC is not a very versatile language for handling large databases, it does offer the following distinct advantages:

(i) Minimum hardware requirements. Only 64K of RAM is needed to run the BASIC program. Although a two diskette drive system is recommended, the programs can be run with a single drive system.

(ii) Minimum software requirements. The BASIC programming language is readily available and the interpreter version is almost always included in the DOS diskette. Compiled version of these programs written in BASIC will be faster to execute.

(iii) Availability of subroutines. BASIC was one of the first languages that were developed for use on the microcomputer, so many ready-to-run

subroutines have been written and tested. These subroutines can be easily interfaced within one's own programs.

(iv) BASIC is simple and easy to learn. This means that it is very easy to obtain the services of programmers who are proficient in the language.

The CRP application software is divided into three distinct modules with several sub programs within each module. They are:

I. Capacity Planning Module.

1. Item/Assembly Inquiry.
2. Input Work Center/Operations Sequence Data.
3. Delete/Replace/Add Sequence.
4. Print Work Center/Operations Sequence Information.
5. Batch Size Determination.
6. Capacity Planning Report.
7. Material Requisition List.

II. Shop Order Processing Module.

1. Detailed Work Center Scheduling.
   (a) Edit Shop Schedule List.
   (b) Early Due Date Schedule.
   (c) Shortest Processing Time Schedule.
   (d) Shortest Remaining Job Slack Schedule.
   (e) First Come First Serve Schedule.
2. Shop Schedule Report.
3. Work Updating and Rescheduling.

4. Shop Status Inquiry.

5. Operation Time History.

6. Shop Work Order Releases.

III. Systems Processing Module.

1. Costing Programs.

(a) Cost Inquiry.

(b) Shop Order Costing.

(c) Historical Costs and Forecasts.

2. Month-end Processing

3. Management Reports Generation.

(a) Performance Measurement Reports.

(b) Exception Reports.

(c) Utilization Reports.

4. Random Inventory Count Generation.

5. Initial System Data Files Setup.

6. Reorganization of Data Files.

7. Chain to Other Programs.

The CRP application software is menu-driven. An individual can go from one program to another by selecting the corresponding number from the displayed menus. The programs themselves are user-friendly and will prompt the user if any errors are detected and ask for confirmation before any action is taken. There are a total of thirty two BASIC programs and eight data files in the system. The CRP system also requires the following MRP system data files,

```
MASTERA.DAT  }
MASTERB.DAT  } Part Master Files.
INDEX  .DAT  }

BOM    .DAT  } Bill of Materials file.
MRP    .DAT  } MRP matrix file.
```

The programs have been designed to be general so that they can be implemented by different companies with very little modification. Some modifications like changing the length of part numbers may be inevitable. The source code of the programs can be obtained from the CRP diskettes and the data records format is presented in the Appendices. Together, they provide enough information for the experienced user to do program modifications and future enhancement of the system. The modules are referred to in the various discussions and a concise User's Manual is included in the Appendices.

2. DATA COLLECTION AND CONTROL

2.1 Data gathering

For any production and inventory system there are essentially two categories of characteristics; one that describes the environment outside the system, and one that describes the environment internal to the system. The selection of data is started by preparing and examining the list of what are thought to be important characteristics. The task of data selection is approached external to the organization by giving consideration to:

(i) The expected sales of each individual product(market research information).

(ii) Customer purchasing patterns, whether periodic, seasonal or random(historical sales data analysis).

(iii) The acceptable time period between receipt of customer order and delivery(market position and competition).

(iv) Desired service level(market position and management policy).

The measurement of the internal characteristics determine:

(i) Capacity and utilization of resources.

(a) Production.

(b) Facilities.

(c) Labour.

(d) Storage facilities.

(e) Material handling and transportation facility.

(ii) Lead times.

(a) Customer order processing.

(b) Production.

(c) Purchasing.

(iii) Inventory.

(a) Classification.

(b) Levels.

The contents of the database of any production and inventory control system should be limited to those items that will be put to good use by the system.

2.2 Part Master and Identification

To be able to keep track of each and every stage of the production process it is essential that each and every part used in the plant has an unique part number that identifies it completely. For Argo Material Handling Ltd. an eight digit alphanumeric part number was developed by Graduate students Evan Hu and Stephen Cheng[3]. The first three digits being alphabetic and the remaining being numeric. Care was taken while designing the numbers to differentiate between finished products, assemblies, subassemblies, components and raw material[13]. The bill-of-material is divided into two sections:

(i) Part Master.

In this section(file), for each item , the following information is stored: part number, name, unit of measure, reference number, supplier data, unit price, and lead time.

(ii) Product Structure.

In this section(file) the relationship between items is specified.

The minimum required data are parent item number, son item number and quantity per assembly. These two sections are connected by a chain address or pointer.

2.3 Time Estimates

In order to assess the capacity requirement and prepare a schedule of jobs to be processed on different work centers it is necessary to make an estimate of the production time for each part. There are two categories of work measurement procedures, direct and indirect[6][33]. The direct work measurement procedure includes (a) time study, and (b) activity sampling. The indirect work measurement procedure includes (a) synthetic timing, (b) pre-determined motion time system, and (c) analytical estimating.

Time study is the most widely adopted method for obtaining time estimates of short cycle repetitive jobs. The simple equations are[33],

Normal Time = Observed Time X Rating Factor

Standard Time = Normal Time/(1- Allowance Factor)

Shop Processing Time = Standard Time / Efficiency

2.4 Manufacturing Routing and Operations Sequence

The data gathered in this phase will clearly state the different work centers through which a part must pass and a description of the various operations performed. When it has been determined how an item will be manufactured, the details are recorded on a route sheet. This is basically an outline of the required manufacturing operations. It is

also referred to as an operation process or instruction sheet, or a manufacturing outline. Route sheets are of primary importance in a business producing a variety of components used on a number of different finished products. The many combinations of operations required to fabricate the various items, coupled with variations in the frequency of production, makes it mandatory that there be a systematic way of recording and using information on how to manufacture. It facilitates production control and provides an instruction plan to the shop. The data so gathered will be the basis on which the machine loading and scheduling will be done while processing a work-order. For each and every part that is found in the part master file this information is to be recorded. The form developed for this purpose is shown in Figure 2.1

2.5 Operations Flow Charts

With the routing and operations sequencing information charts are prepared that describe the flow of work and the interrelationships between the parts. Flow process charts can be either schematic, or detailed[2][15][33]. In a schematic flow process chart the various activities performed in the shop to manufacture a part/product is schematically described along with the operational times for each operation. Detailed flow process charts on the other hand describe each and every operation performed in the shop along with the operational times. While the schematic chart does not describe the operations as is done in the detailed flow process chart it is more useful in finding out the various jobs that are processed in the same work center. Sample charts are shown in Figure 2.2 and Figure 2.3

ARGO MATERIAL HANDLING SYSTEM LTD.
ROUTING SHEET / OPERATIONS SEQUENCE

PART NUMBER :

DESCRIPTION :

OPN. #	OPN. DESCRIPTION	WORK CENTER #	TIME PER UNIT			REMARKS
			SETUP	PROC.	TOTAL	
						ASSY. #

Prepared by: | Verified by: | Revision # | Date:

FIGURE 2.1 ROUTE SHEET / OPERATIONS SEQUENCE FORM

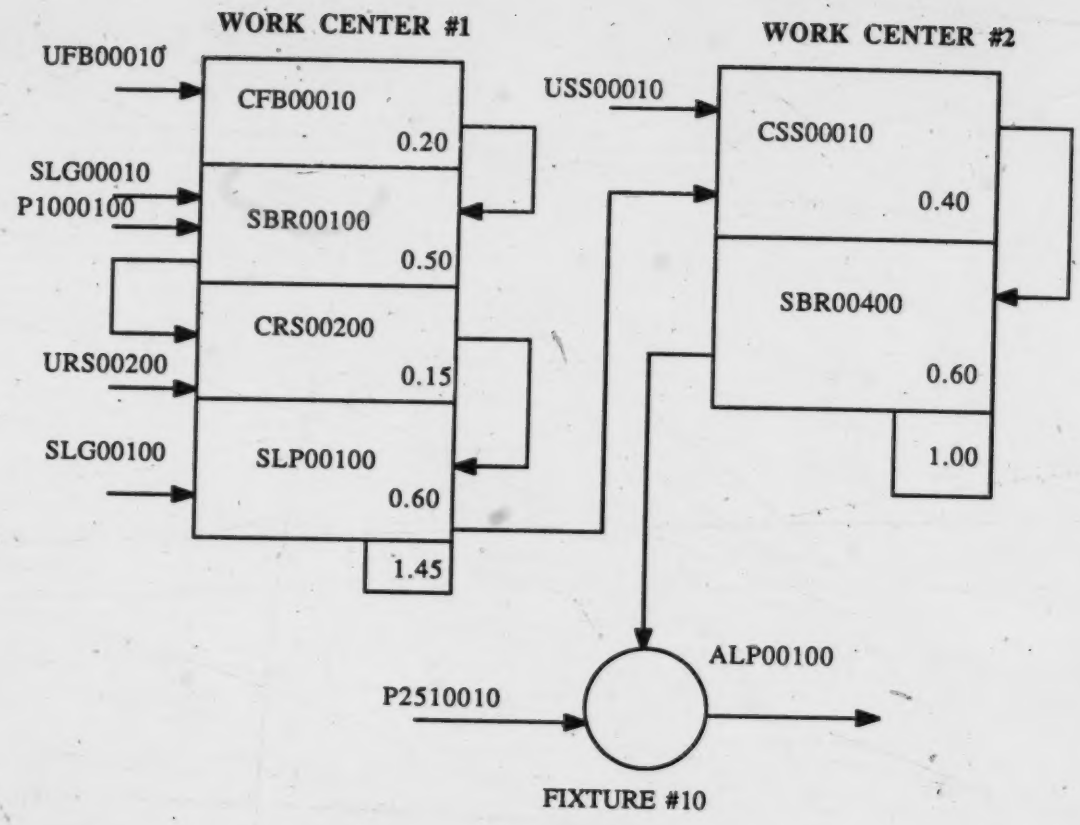


FIGURE 2.2 SCHEMATIC FLOW CHART

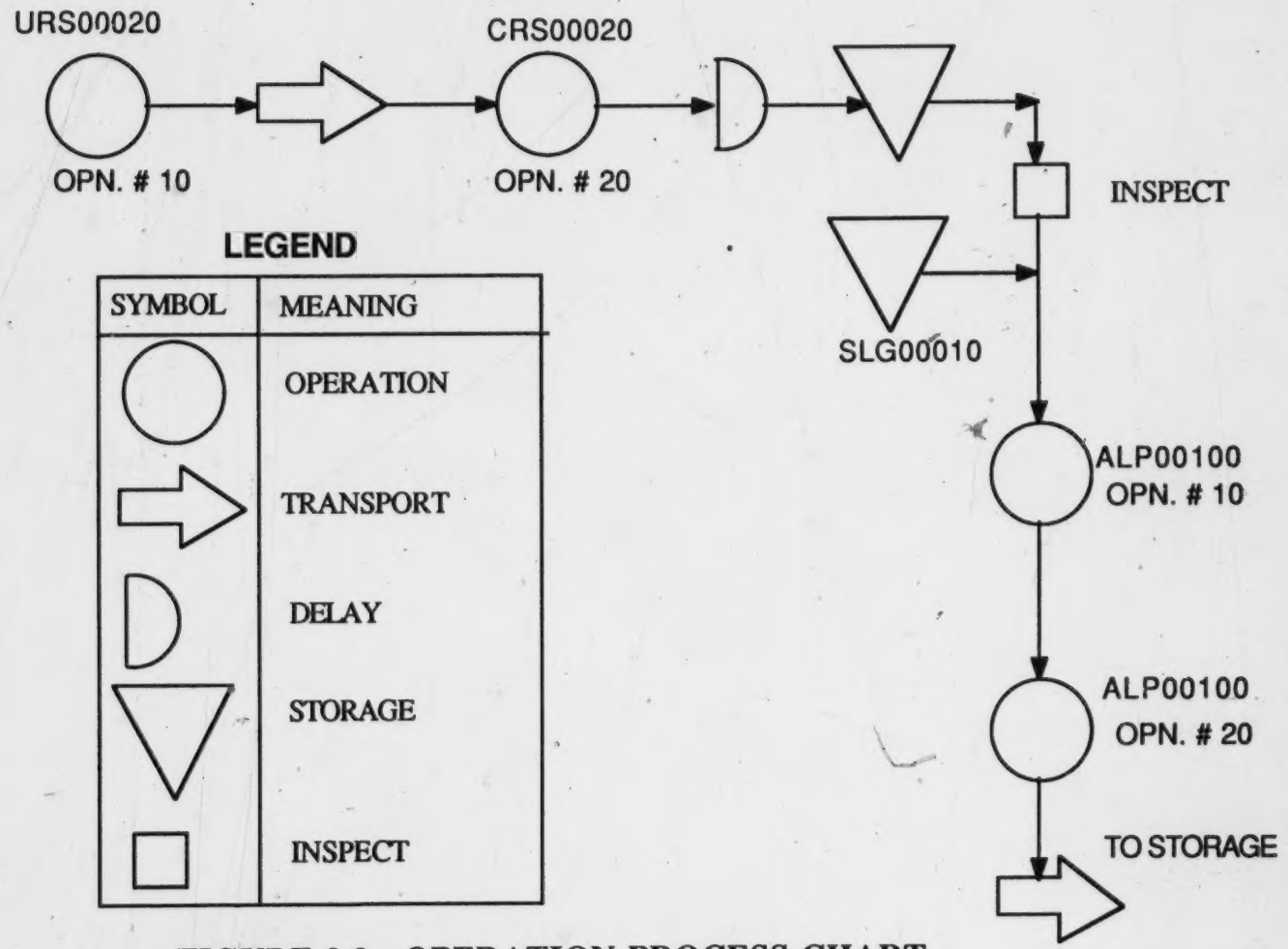


FIGURE 2.3 OPERATION PROCESS CHART

2.6 Data Collection for Argo Material Handling System Ltd.

To plan and control plant utilization management needs first class standards. Effective scheduling depends on the company's ability to project demand accurately and translate this into facility requirements. Then, strategies can be developed to work around any limiting factors and to exploit under utilized facilities. The key ingredient for this entire scenario is the production standard. The company must know the standard time required to process or manufacture each product and the information must be available for each production center. Anticipated performance must also be known. These basic requirements must be taken care of before any planning can be done[33].

For the study done at Argo Material Handling System Ltd. it is recommended that schematic as well as detailed operation process charts be drawn as both are required to completely analyze the shop floor activities. The information regarding the various work centers and the operations sequence information for the various parts have been collected and the data bases have been set up to be used by the capacity planning module. The information gathered is presented below.

The information regarding the various work centers has been collected keeping in mind the requirements of the Capacity Planning Module. Care has been taken while designing the various fields so that the information gathered is complete. A sample screen input is presented in Figure 2.4, below and the fields are explained.

1. **WORK CENTER # :[ ]**. A 3 character work center number has been

```
15-06-88                WORK CENTER DATA              PROG:WORKCENT

 1. WORK CENTER # :[A02]     2. WORK CENTER NAME :[LATHE          ]
 3. LOCATION      : A11      4. DESCRIPTION      :[TURRET LATHE   ]
 5. NORMAL CAPACITY:500.0    6. MAX.CAPACITY:    900.0
 7. EFFICIENCY FACTOR: 95.0
                             8. SET UP RATE      :   6.00

 9. MACHINE RATE  :   14.00 10.LABOUR RATE       : 12.00
11. OVERHEAD RATE :    4.00

            A(mend)     U(pdate)     I(gnore)
```

FIGURE 2.4 SAMPLE WORKCENTER DATA MENU

designed. It may be advisable to use an ordered sequence for work center number, that will give some idea about the work center. It may be helpful to have an alphanumeric code, for example A01. This may denote work center '01' in department 'A'.

2. WORK CENTER NAME :. The work center name can at most be 25 characters long. Work center names may be 'drilling m/c', 'capstan lathe', etc.

3. LOCATION :. The location code is designed mainly to deliver raw material to a particular work center or to move a part being processed to its next operation. The location code is also '3' characters in length. It is advisable to use an ordered sequence for location code that gives some idea of the location of the work center.

4. DESCRIPTION :. This field contains a maximum of 25 characters and is designed to contain information about the work center other than what is entered under the work center name.

5. NORMAL CAPACITY :. Depending on the company policy this field

will have different values. This is the 'normal capacity' in minutes for the work center. For example, if a company operates only a single shift of 8 hours duration, and if it is observed that the effective production time available during the shift is 7 hours, then the 'normal capacity' in minutes for the work center is 420(minutes). Needless to state that the normal capacity must always be positive.

6. **MAX.CAPACITY**:. Like the above, this field will have different values depending on company policy. If the company policy is not to work overtime, this value will be the same as 'normal capacity'. However, if it is possible to work overtime or an extra shift(if needed) the additional time available(in minutes) must be added to the 'normal capacity'. For example, considering the work center described in field #5 above, if an additional 3 hours can be made available then the 'max.capacity' is 600(minutes).[7 +3 hours]. Max. capacity cannot be less than the normal capacity.

7. **EFFICIENCY FACTOR** :. It is always advisable to build in some allowance for rejects or scrap. The efficiency factor will take care of this. The efficiency factor is usually given as a percentage. If you feel that the scrap or rejection rate is 10%, then the efficiency of throughput of the work center is 90%. This field cannot be negative or zero.

8. **SET UP RATE** :. If the setting up operations are done by a different crew team, it may be necessary for costing purposes to know the rates applicable for the crew. This is in $/HR. This field also cannot be negative.

9. **MACHINE RATE** :. Depending on the work center, the machine rate is the $/HR that the company spends just to keep the work center operating. This includes power etc.

10. **LABOUR RATE** :. Depending on the skill level required to operate the work center, this rate is entered in $/HR.

11. **OVERHEAD RATE** :. This is the rate for calculating overhead charges for the work center. It is also in $/HR.

The rates entered above will be updated on a periodic basis.

The operations sequence information is required for scheduling purposes. A sample screen input is presented in Figure 2.5 and the fields are explained.

```
15-06-88                  OPERATIONS SEQUENCE          PROG:OPSEQ

PART NUMBER :[CFB22000] DESCRIPTION :[ 2x3 FLAT BAR x1 THICK  ]

1. OPN.# : 10
2. OPN. NAME : SHEAR
3. WORK CENTER # : A10
4. SET UP TIME : 15.0
5. PROC. TIME  : 0.10
6. ALT WORK CENTER # :

      A(mend)      U(pdate)      I(gnore)
```

FIGURE 2.5 SAMPLE OPERATIONS SEQUENCE MENU

1. **OPN.#** :The operations number of a part denotes the sequence of operation. An operations number cannot be negative. Two operations cannot have the same number. The normal practice is to number operations in increments of 10, so that any new operation can be inserted in the sequence at a later date if the need arises.

2. **OPN. NAME**:The operation name is the description of the operation. It can at most be 30 characters long.

3. **WORK CENTER #** :The work center number is the number of the work center where the operation will be done. The work center number is 3 characters long and the number must exist in the work center file.

4. **SET UP TIME**:This is the time in minutes it takes to set up the work center before the operation for the part can be started. It cannot be negative.

5. **PROC. TIME**:This is the time in minutes it takes to complete the operation for one piece. It cannot be negative.

6. **ALT WORK CENTER #** :This is optional. If the specified operation can be done in more than one work center then that information can be used while scheduling jobs to work centers. If you enter this field, then the work center chosen must exist in the file.

The work center and operations sequence information form the data base that feed the information to the Capacity Planning Module. The programs developed to set up these data bases are very flexible and allow copying duplicate information from an existing part to another part thereby reducing the amount of time spent on inputting data. The programs also allow for editing the existing information stored in the databases.

3. CAPACITY REQUIREMENTS PLANNING MODULE

3.1 Overview of Capacity Requirements planning

3.1.1 Manufacturing Activity Planning

Manufacturing activity planning is concerned with the overall operation of an organization over a specified time horizon. It is known by such names as aggregate planning, aggregate scheduling, and operations planning[25]. From forecasts and customer orders, production planning determines the human and material resources required to produce the output demanded in an efficient manner. The goal is to effectively allocate system capacity (plant, equipment, and manpower) over a designated time horizon. The production plan indicates the organization's strategic position in response to the expected demand for its outputs. A good production plan should:

(i) Be consistent with the organizational policy.

(ii) Meet demand requirements.

(iii) Be within capacity constraints.

(iv) Minimize cost.

Production planning deals with output in broad terms. Usually a single overall measure of output or a limited number of product categories are planned. Aggregates such as tons of output, hours of equipment time, or number of customers are used. The aggregation of products into a common output unit substantially simplifies the planning process. It permits top management to allocate resources in a general way without being engulfed in specific details. The production planning

function shown in Figure 3.1, devises the production strategy in relation to aggregate levels of demand. If the demand for a product or service were constant, the planning activity would be trivial. With variability in demand production planning takes on significance. The major strategy variables associated with production planning for variable demand are the production rate, the inventory level, the work force size, extra shifts, overtime, the product mix, and subcontracting. These strategic variables can be varied, modified, fixed, or nonexistent for any organization depending on its peculiarities and policies.

3.1.2 Master Schedule and Customer Orders

A master schedule(also known as a master production schedule(MPS)) shows the kinds and quantities of products to be provided in each time period in the future. It translates the production plan into specific products or product modules and specifies the time period for their completion[2][9][19]. Moreover, it can generate detailed material requirements and capacity planning information which enable it to balance demand against resources. The master scheduling function is shown in Figure 3.2. In some organizations it may be difficult to differentiate between the production plan and the master schedule. The master schedule is derived from the production plan but contains greater details. The production plan deals with aggregate planning for total output, while the master schedule usually relates to specific products or end items. Normally a production plan covers a time horizon from 6 to 24 months and is updated monthly. A master schedule is formulated within the time horizon of the production plan and is updated weekly. The master schedule

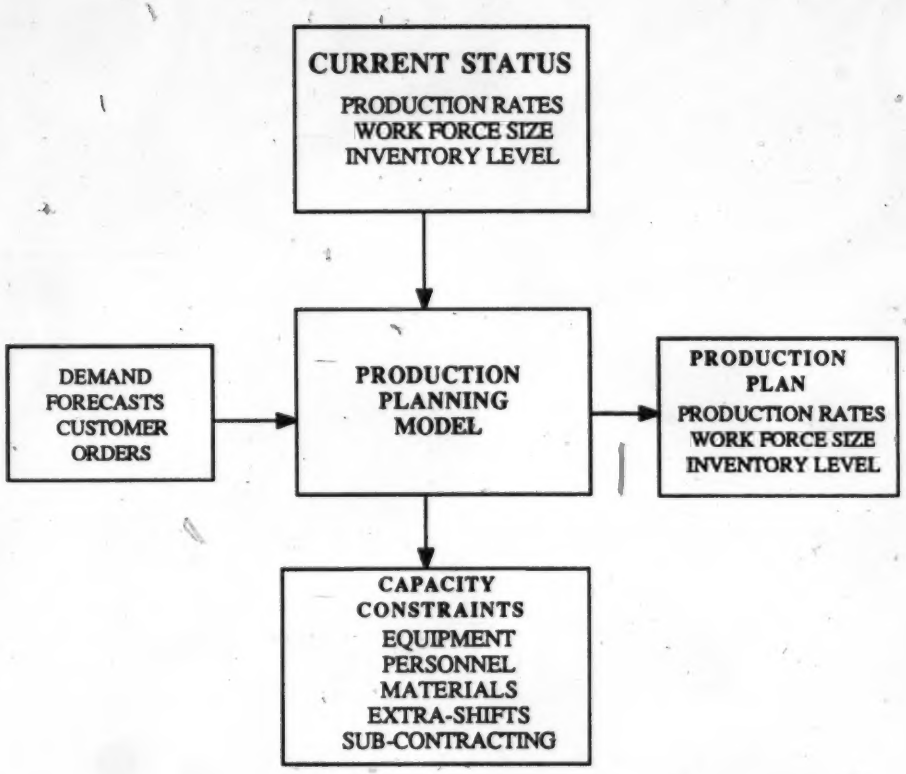


FIGURE 3.1 PRODUCTION PLANNING FUNCTION

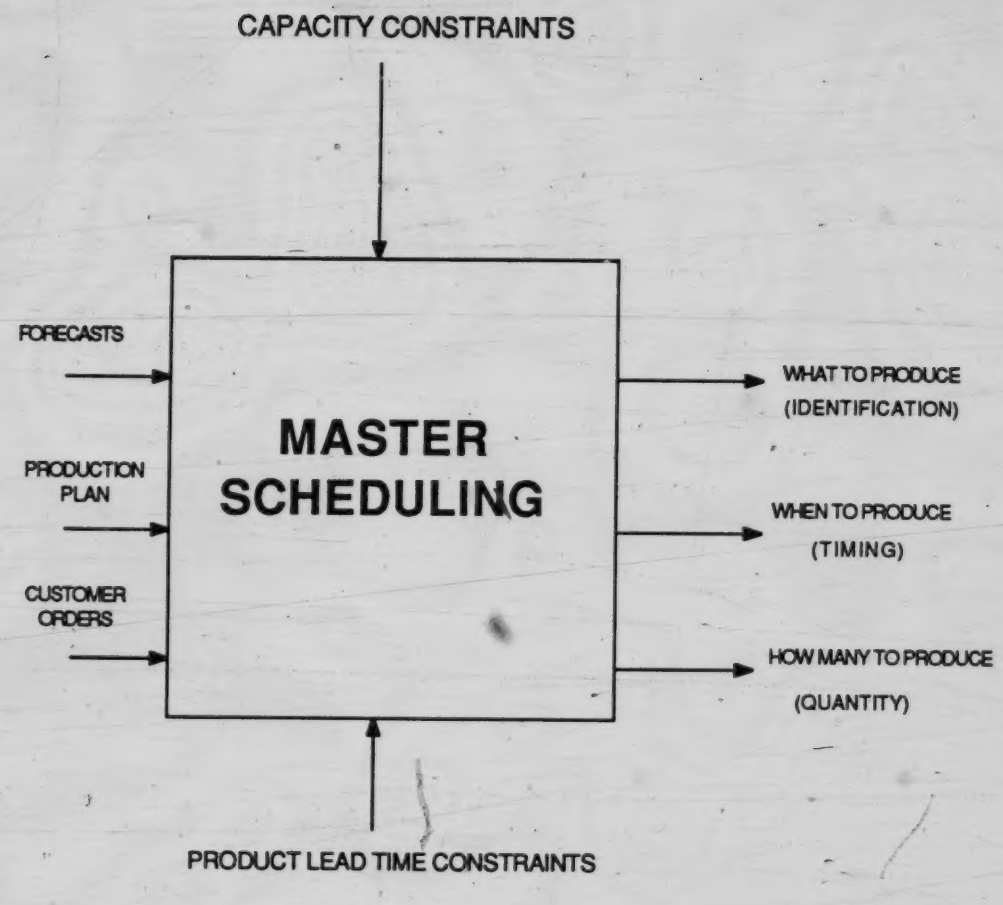


FIGURE 3.2 MASTER SCHEDULING FUNCTION

should be somewhat longer than the sum of cumulative lead times of component parts, subassemblies, and final assemblies. Within the confines of the production plan, the master schedule must balance material and capacity requirements. Providing material when capacity is not available results in excess inventory investment. Providing capacity when material is not available results in low productivity. The master schedule is the plan which takes care of these problems.

The inputs to the master schedule are the demand forecasts and customer orders. Customer orders are the basis for releasing shop planned orders. The customer order processing and details of master scheduling were done by another Graduate student Stephen Cheng[3].

3.1.3 Batch size determination

The current trend in the overall business scenario is to move towards the Japanese concept of just-in-time(JIT), or the more widely acclaimed zero inventories. While one cannot deny the advantages of the above concepts, when adopted by an organization specializing in typical job-shop activities, lost orders and poor delivery schedules may result. Batch production is the conventional way to utilize limited facilities to the maximum. Batch production is required(over successive production runs) to:

(i) Reduce production lead time.

(ii) Increase utilization of facilities and reduce idle labour time.

(iii) Load balance.

There are several methods that can be employed for lot sizing. A few of these are:

(i) Lot-for-lot.

(ii) Classical economic batch quantity.

(iii) The economic time cycle model.

(iv) The least unit cost algorithm.

(v) The least total cost algorithm.

(vi) Wagner-Whitin algorithm.

A brief discussion on the first two are presented below. A detailed discussion on others can be found in any text book[8][19][25][26][29][30].

(i) Lot-for-lot : Lot-for-lot is the name given to the method that orders exactly what is required in each period. Planned order releases are matched to net requirements. Lot-for-lot ordering implicitly assumes that setup or ordering cost is much smaller than carrying cost.

The MRP programs developed by Stephen Cheng assumes a lot-for-lot policy.

(ii) Classical economic batch quantity formula: The basic formula for the economic batch quantity(EBQ) can be written as[8][9][11],

Q = √ ((2 * S * D) / C) ;in which,

S = cost of single set-up for a batch

D = demand for the time period considered

C = inventory holding cost of carrying one item for one time period as stock.

The policy implied by the use of this formula is that whenever stock reaches the reorder level(that is, a quantity sufficient to cover the

expected demand within lead time plus a safety stock) a quantity 'Q' will be ordered.

The CRP programs have this method of batch sizing and an EOQ can be computed for any part. The lot sizes determined by using one of the above methods is only a guideline. Usually in a production shop it may not be possible or advisable to strictly follow the lot sizes and smoothing is done regarding lot sizes. This is done mainly to reduce raw material stock that may be left over by rigorously following one of the formulas, which increases handling and material accounting problems.

3.1.4 Resource Requirement Planning

The term used in connection with the long range planning of the capacity at the master production schedule level is Resource Requirement Planning(RRP)[19][25]. The objective or goal of the RRP is:

(i) To assess any imbalance between the planned factors that affect capacity and the long term master production schedule.

(ii) To determine the appropriate capacity of facilities, equipment and labour needed in the future.

(iii) To establish a time phased plan for acquiring additional capacity or reducing existing capacity.

A flow chart for resource requirement planning is shown in Figure 3.3. The process begins with an assessment of long-range forecasts and

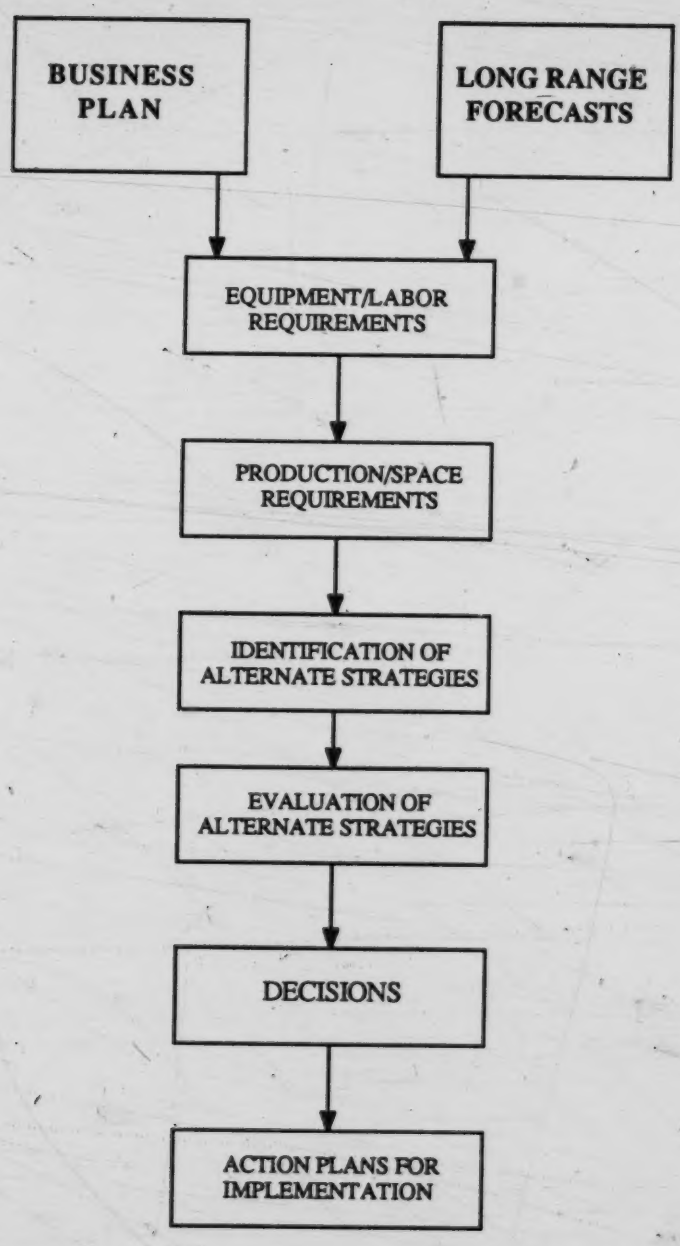


FIGURE 3.3 THE RESOURCE REQUIREMENTS PLANNING PROCESS

strategic objectives. Forecasts of demand for products and services must be translated into specific equipment and labour needs. The next step is to identify strategies for meeting future capacity needs. For example, equipment needs might be met by replacing old machines with new machines or by purchasing additional machines. In addition marketing strategies, such as phasing product life cycles to maintain constant levels of resource requirements, represent other alternatives. Once a decision is taken an implementation plan is developed to coordinate the timing of capacity decisions in relation to needs. These plans are then communicated downward to the lower level personnel for implementation.

3.2 The Design of the Capacity Requirements Planning Module

The maximum level of output for a facility is its capacity. For organizations with a single or a few products, capacity is easily determined. For multi-product organizations, capacity is more difficult to measure when the products share facilities. Capacity must be related to a time frame and is usually stated as a rate(quantity of output in a given time). It can be on a single shift or multi-shift basis. It is only a theoretical level of output which may not be attainable. Frequently as the capacity level is approached efficiency drops and costs increase rapidly. Operating at 100% capacity is a rare if not unattainable accomplishment because of equipment breakdowns, personnel vacancies, and absenteeism. Capacity planning decisions involve both long term and short term considerations. Long term considerations relate to overall level of capacity, such as facility size, while short term considerations relate to probable variations in capacity requirements

created by such things as seasonal, random, and irregular fluctuations in demand. The time intervals covered by each of these categories can vary significantly from industry to industry and it would be misleading to attempt a precise definition of these terms.

3.2.1 Objectives of the Module

The principal objectives of the designed capacity planning modules are:

(i) To determine available capacity with a view to confirm MPS requirements.

(ii) To determine overloads and bottleneck work centers.

(iii) To indicate proper sequence of order production to meet committed schedules.

(iv) To indicate the possible need to subcontract work or to purchase instead of manufacture.

(v) To measure production performance in relation to the shop load period, and to indicate the need to reschedule orders which have not been produced as planned during the expired period.

3.2.2 Capacity Planning Techniques

The most common capacity planning techniques[2][19][20][33] are:

(i) Graphical technique: Work center load charts are an example of this type. They are easy to understand and visualize.

(ii) Linear programming technique: Since capacity planning can be formulated as a LP problem it can be solved by this method.

(iii) Miscellaneous techniques : Numerous other analytical, heuristic, simulation, and computer search techniques have been developed. None of these techniques have gained widespread acceptance. Frequently their input requirements and assumptions seriously limit their application.

The capacity planning technique incorporated in the CRP program is similar to the graphical technique. The MRP matrix contains information on the various parts that need to be produced during the current plan period. This information is read and an EOQ will be planned for the parts. The information regarding the routing and the work centers will then be read in and work loads will be found for the different work centers. A comparison with the work center capacities will then reveal if there is sufficient capacity or not.

3.2.3 Capacity Requirements Planning Module

The capacity planning module developed as part of the CRP software package consists of three kinds of programs, viz. (a) inquiry program, (b) data input/editing programs and (c) capacity planning programs. The various programs are listed below.

1. Item/Assembly Inquiry.
2. Input Work Center/Operations Sequence Data.
3. Delete/Replace/Add Sequence.
4. Print Work Center/Operations Sequence Information.
5. Batch Size Determination.
6. Capacity Planning Report.
7. Material Requisition List.

The first is an inquiry program meant to supply information to the decision maker regarding any specific part/assembly. The next three programs are used to set up the work center and operations sequence databases that drives the CRP. The last two programs are the outputs of capacity planning.

3.2.4 Data for Capacity Planning

The data requirements for capacity planning are:

(i) Valid due dates on all released and planned orders.

(ii) Up-to-date routing and processing information.

(iii) Accurate standards for processing and set-up times.

(iv) Estimates of load due to unplanned occurrences.

The due date information is built into the MRP matrix while computing the net requirements. The routing and processing time information is available in the CRP database. The estimate of load due to unplanned occurrences is input by the planner during the execution of the capacity planning report program.

3.2.5 Capacity Planning Report Program Logic

The flow chart for capacity planning is shown in Figure 3.4. The inputs to the requirements plan originate in the MRP as a Master Schedule, which essentially is a parts explosion on a time frame. The MRP matrix contains the Net Requirements for each and every part in the master file for an eight week period. A sample of the MRP matrix is shown in Figure 3.5. The Capacity planning module reads this information and develops the needed input of the requirements plan. The parts to be

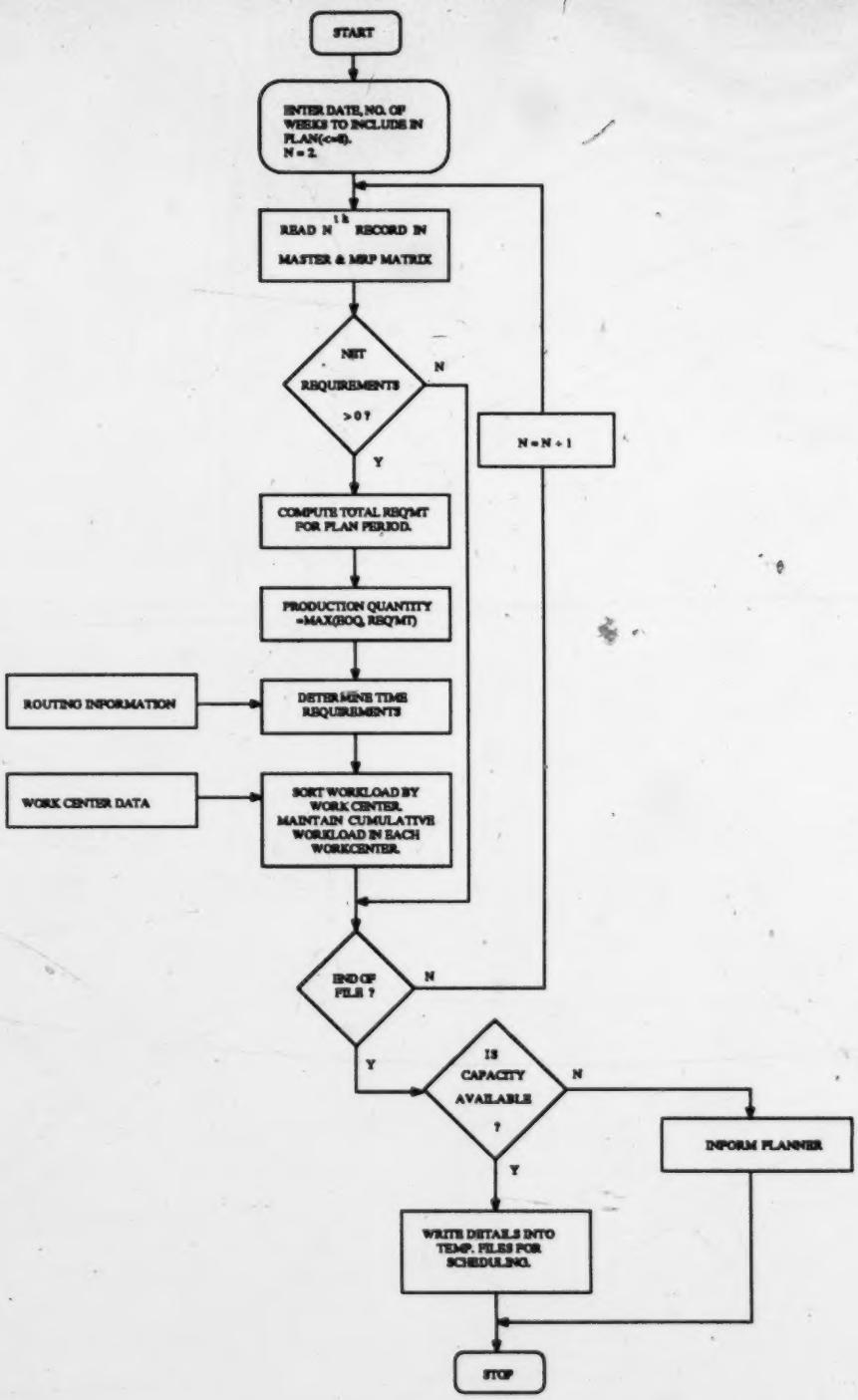


FIGURE 3.4 FLOWCHART FOR CAPACITY REQUIREMENTS PLANNING

PART NO.: AAAA0001	DESC.: SUPPLY/TAKE-UP REEL-						LEAD TIME : 2	
SAFETY STK.: 0 STARTING BAL.: 20	@12/03/87			PERIOD (WEEK)				
	11	12	13	14	15	16	17	18
GROSS REQUIREMENTS	0	0	0	0	0	160	180	0
SCHEDULED RECEIPTS	0	0	0	0	0	0	0	0
PROJECTED AVAILABLE	20	20	20	20	20	-140	-320	-320
NET REQUIREMENTS	0	0	0	0	0	140	180	0
PLANNED ORDER RELEASES	0	0	0	140	180	0	0	0

FIGURE 3.5 SAMPLE MRP MATRIX

produced during the planning period are then subject to their technological ordering and a work list is prepared showing the quantity to be produced and which machines need to be used. The capacity requirements planning is done on an expected value basis. The time required to produce the quantities are aggregated and compared to available capacities and overloads, if any are revealed, so that the MPS can be altered or other action initiated. The results of the capacity requirements planning phase is the capacity planning report shown in Figure 3.6 .If there is enough capacity available to meet all the requirements then detailed shop order releases can be made and the required materials can be issued by the materials requisition list.

This capacity check presents capacities and loads by variable time periods within a facility(work center). It helps the user make both short term and long term decisions. The period lengths in short term planning should be small so that decisions regarding overtime can be made. These decisions result in the short term capacity changes that are required if the Master schedule is not to be altered. In the long term planning, the

ARGO MATERIAL HANDLING SYSTEM LTD.
CAPACITY PLANNING REPORT
Page _ of _

PLAN PERIOD :*dd/mm/yy* to *dd/mm/yy* *dd/mm/yy*

WORK CENTER #	CAPACITY (HRS.)	ESTIMATED LOAD (HRS.)	PERCENT OF CAPACITY	REMARKS
A01	200.00	160.00	80.00	
A10	200.00	180.00	90.00	
B20	160.00	200.00	125.00	OVERLOAD
B99	100.00	100.00	100.00	CRITICAL LOAD

FIGURE 3.6 CAPACITY PLANNING REPORT

user must decide between delay or capacity changes of a more general nature, viz., labour adjustments, new facilities or sub contracting. This information is of the utmost importance to the production manager.

Capacity requirements planning matches the planned load against the available capacity. At this stage the user has the ability to review the orders on hand to rearrange the order due dates, if needed, or sub contract selected orders. Conversely it is possible that without such action, orders representing the overloads will be further delayed because of capacity limitations.

It is important in any production control system to provide enough flexibility so that necessary revisions which result from customer's requests, engineering changes, and planning and scheduling requirements can be made easily and in a controlled manner. Changes arising due to changes in customer orders are taken care of in the MRP and a regeneration of the matrix is executed. Changes arising from such factors as delays due to machine breakdowns and the like will be taken care of by CRP before any planning run is made.

4. SHOP ORDER PROCESSING MODULE

A scheduling problem exists when a large number of interdependent activities are required to use the same limited facilities. Due to the numerous possible combinations, the solution to this problem involves processing a large amount of data on a repetitive basis. This problem can rarely be solved satisfactorily using manual techniques. It can be analyzed manually at any point in time relative to a given resource, but the resulting decisions in terms of the full time range and other resources cannot usually be visualized[33]. Consequently, management must spend much of its time trying to correct this situation. It is exactly for this reason that a computerized scheduling system is a useful tool. The major objectives of the designed scheduling system are to assist management in:

(i) Meeting due dates.

(ii) Reducing lead time of orders, thereby reducing W-I-P.

(iii) Minimizing idle time on available resources.

(iv) Providing management with an up to date and feasible solution.

4.1 Job Sequencing Perspective

The job sequencing problem is considered to be one of the most interesting problems in production analysis. The problem is quite complex and difficult to solve[24]. Optimal solutions can be found for job sequencing problems with a small number of machines. However, optimal

solutions for problems with a large number of machines do not exist.The job sequencing problem can be stated as "Given n jobs to be processed, each has a setup time, processing time and a due date. In order to be completed, each job is to be processed at several machines. It is required to sequence these jobs on the machines in order to optimize certain performance criteria".

A typical list of performance criteria to be optimised is:

(i) Mean flow time or mean time in shop.

(ii) Idle time of machines.

(iii) Mean lateness of jobs(lateness of a job is defined as the difference between actual completion time of the job and its due date. Earliness/tardiness are different forms of the same measure).

(iv) Mean queue time.

(v) Mean number of jobs in the system.

(vi) Percentage of jobs late.

The factors that serve to describe and classify a specific scheduling problem are:

(i) The number of jobs to be scheduled.

(ii) The number of machines in the system.

(iii) Type of manufacturing facility(flow shop or job shop).

(iv) Manner in which jobs arrive at the facility (static or dynamic).

(v) Criterion by which scheduling alternatives will be evaluated.

The first factor defines the exact number of jobs to be processed, the time required for each process and the type of machine needed (available from the operations sequence information). The second factor defines the number of machines in the system(available from the work center database). The third factor describes the flow of jobs through the system. If the flow is continuous and the jobs require the same sequence of machines, we call it a flow shop pattern. In situations where there is no common pattern for the flow of jobs through the system, a job shop pattern is said to exist. The fourth factor describes the arrival pattern, and is classified as either static or dynamic. In the static pattern, there are 'n' jobs, each of which must be processed by a set of machines. All of the 'n' jobs are available for processing at the initiation of the scheduling period and no new jobs arrive during the period. In the dynamic pattern, jobs arrive intermittently according to a stochastic process. The fifth factor describes the use of one or more of the performance criterion mentioned earlier.

Although some progress has been made in the flow shop sequence problem, little significant progress has been made in the job shop sequencing problem. This is due to the large number of complex factors that exist in the job shop environment, such as the fact that the jobs do not have the same technological ordering. Because of the complexity of these problems, nearly all reported studies have resorted to simulation as a research tool[9][24][33]. The most common scheduling rules for job shop environment are:

(i) RANDOM - Select the jobs at random.

(ii) FCFS - Select the jobs on a first-come-first-serve basis.

(iii) EDD - Earliest due date. Select the jobs with the earliest due date.

(iv) SPT - Select the job with the shortest processing time.

(v) LRPT - Select the job with the least remaining processing time.

(vi) S/OPR - Select the job with the minimum ratio of job slack time/number of operations remaining.

(vii) ODD - Select the jobs with the earliest operational due date.

(viii) LSTART - Select the job with the earliest late start time.

(ix) OSLK - Select the job with the least operational slack.

These rules are self explanatory.

There is a dynamic aspect to the job shop scheduling problem. A schedule for the current set of jobs is produced(by some method, for example, EDD) and as this schedule is being worked through new jobs arrive at the system. There are two extremes for scheduling the new jobs. One is to produce a new schedule each time a new job arrives. The other is to completely finish the existing schedule before producing a new

schedule for the jobs that have arrived in the meantime. The latter extreme changes the problem from a dynamic job shop to a static job shop. Alternatively a solution in between these two extremes is a possibility for using an on-line computer system. Every time an operation is completed on a machine, the information is fed into the computer and the programs then consider the actual status of the shop at that time and with all the relevant information and criteria chosen selects the next job for that machine. Clearly the computational implications of this are considerable and in many cases may not be economically feasible. Consequently, less frequent re-scheduling must be considered.

4.2 Scheduling Steps

This phase of activity can be easily understood by following the steps mentioned below:

1. Choose a work center.
2. Choose a schedule period.
3. Choose a scheduling method.
   - (i) Set priority on orders.
   - (ii) Set work center capacity limits.
   - (iii) Define alternative work centers.
   - (iv) Load work center in priority sequence.
   - (v) Select alternative work centers.
   - (vi) Reschedule over loads.
4. Revise as necessary.
   - (i) To update, remove completed work, add new work and

start over again.

4.3 Work Order Number

A job order or work order number is similar to a purchase order number or a customer order number. It is used to identify a set of jobs that the shop will process. Work order numbers will assist in:

(i) Tracing materials issued to the shop, so that the direct material cost can be calculated.

(ii) Follow up work being processed.

(iii) Accumulate time spent on a particular lot so that the direct labour cost can be calculated.

(iv) Analyze historical data.

There are different ways of numbering work orders. One method is to issue a work order number for each individual customer order. This will greatly facilitate in follow up activities. The drawback of this method is that there might be different order numbers for the same part being processed covering different customer orders. The MRP matrix contains the total net requirements of the part for the planned period and does not identify specific quantities to specific orders explicitly. Moreover the CRP plans for an EOQ to be produced and this means that the production quantity may be greater than the immediate requirements of the customers. Considering these facts, work order number has been assigned to work schedules being sent to the shop and a manual follow up is recommended at the final assembly stage to identify the finished product with specific customer orders. An eight digit work order number has been

designed. The first two digits being the company name, the next two being the number of orders released on a day, and the last four being the day and month. For example, AR011506 denotes the first order released on June 15. The incorporation of the day and month into the work order number facilitates in fast retrieval of historic data.

4.4 Details of the Shop Order Processing System

The shop order processing module consists of the following programs.

1. Detailed Work Center Scheduling.
   - (a) Edit Shop Schedule List.
   - (b) Early Due Date Schedule.
   - (c) Shortest Processing Time Schedule.
   - (d) Shortest Remaining Job Slack Schedule.
   - (e) First Come First Serve Schedule.
2. Shop Schedule Report.
3. Work Updating and Rescheduling.
4. Shop Status Inquiry.
5. Operation Time History.
6. Shop Work Order Releases.

The flow chart for scheduling is shown in Figure 4.1. The input to the sequencing module comes from the capacity planning phase where a check has been made to find out if there is enough capacity available to develop a realistic schedule. The actual scheduling is essentially a sequencing task following a sequencing rule(due date for example). The work load is prepared for each work center for the scheduling period. This scheduling takes place in two stages as follows:

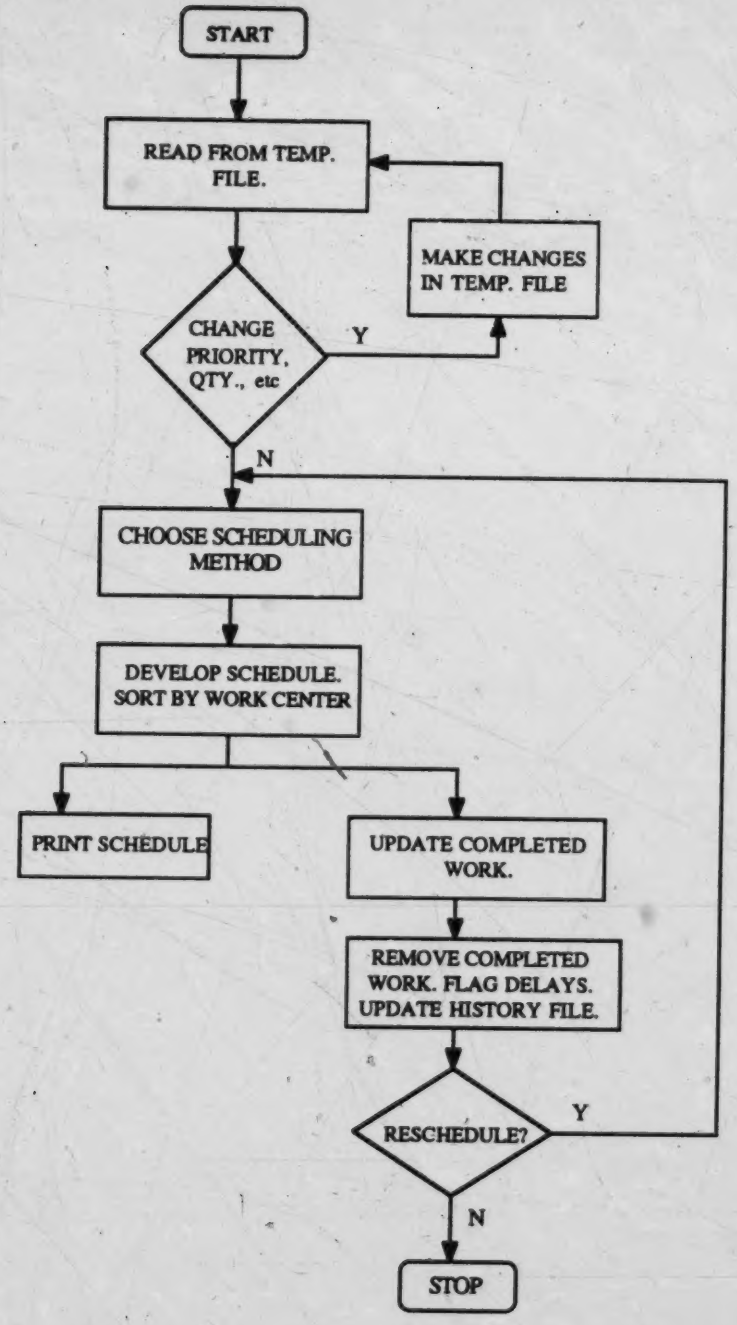


FIGURE 4.1 FLOWCHART FOR SCHEDULING

(1) **Overview** - the total work load for the week is known to the shop planner.

(2) **Detailed** - the work to be performed for the day is scheduled and released to the shop.

The overview is designed to give the planner some flexibility on the actual work and to identify bottle neck facilities that may be expected in the near future if there is a delay in work. Each part in the requirements list is analyzed to determine whether it can pass through the work centers or whether a delay may be expected. This information is essential because most orders may involve penalties for tardy deliveries. The essence of the sequencing problem can be illustrated by a simple example. Suppose Argo has received orders for two products A and B, which are both manufactured in a definite two-step process. The first operation is performed in work center 1 and the second in work center 2. The time requirements for the two products is given in Table 4-1.

	Machine processing times	
Product	Work center 1	Work center 2
A	4(hrs)	12(hrs)
B	8(hrs)	6(hrs)

TABLE 4-1 TIME REQUIREMENTS FOR ORDERS

The scheduling problem is to determine how to process these two products in the shortest possible time. Since operation 1 must precede operation 2 , only two production sequences are possible. Either product A or product B can be processed first. Figure 4.2 depicts the relative apportionment of time under each production sequence. It can be seen that if A precedes B the total time required for processing will be 22 hours, while if B precedes A the total time becomes 26 hours. Clearly it would be preferable to process A before B(It may be pointed out that this is the SPT scheduling rule- schedule the job with the shortest processing time first). Application of the graphical method is limited to relatively simple problems. If the number of products to be made were increased and if all of them had to be processed through these two work centers then the number of possible combinations increase and it would be unwise to resort to graphing each and every possible combination to pick out the best sequence. It is for this very purpose computers are used for sequencing work. The capacity planning module after processing has the work load for the period under consideration. This information essentially includes part number, quantity, and the routing information. The Scheduling module reads this list and categorizes work into 'gateway' operations and 'secondary' operations. The priority of scheduling work is set to be normal by default unless it is a rush order or delayed order from the previous period. In order to differentiate between the various parts that need to be scheduled, a priority system has been designed. The list of priorities designed for use at Argo is shown in Figure 4.3.

Parts with a low priority value(high priority) will be scheduled

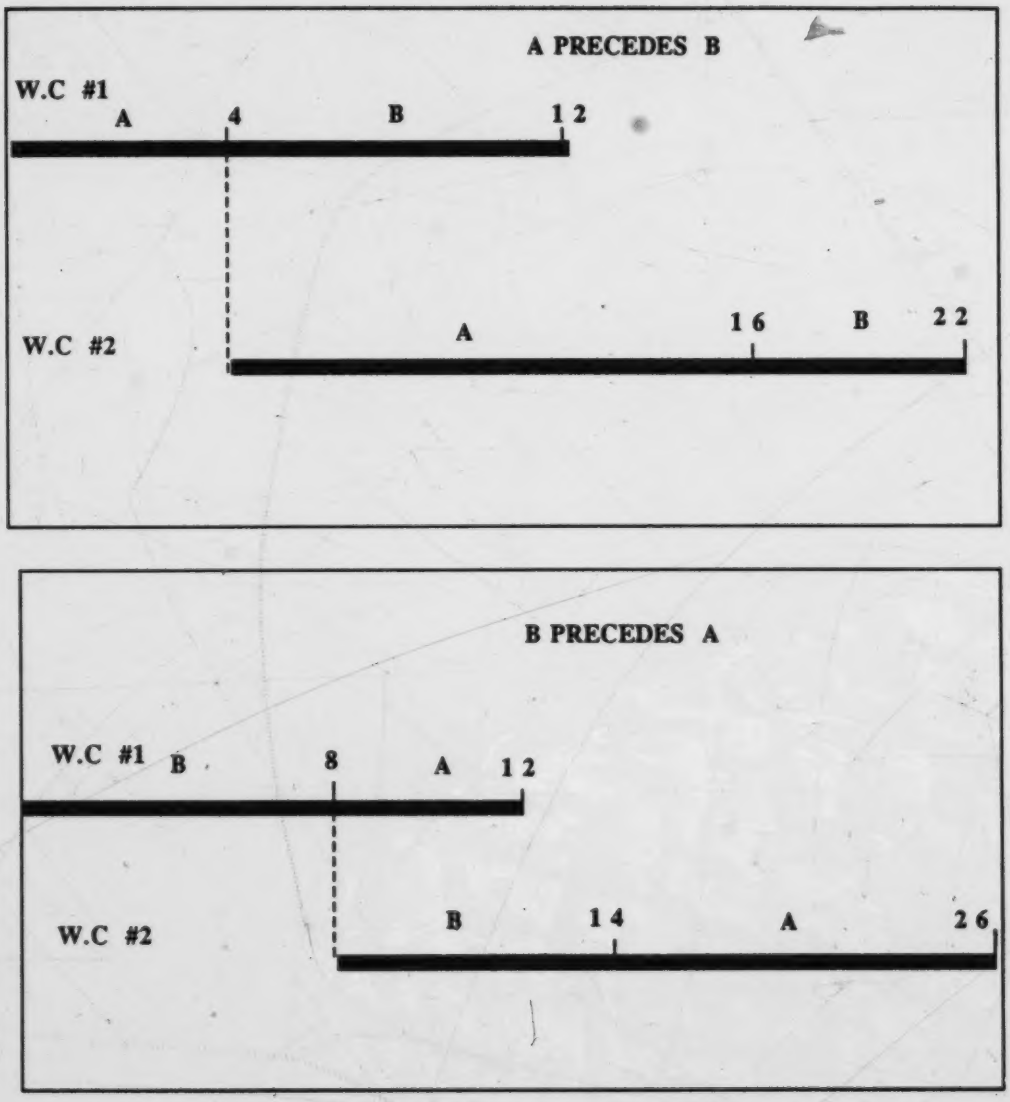


FIGURE 4.2 GRAPH OF SEQUENCING PROBLEM

ARGO MATERIAL HANDLING SYSTEM LTD.

PRIORITY VALUE	PRIORITY CODE	EXPLANATION
0	U	Urgent work. Highest priority.
1	R	Rush job.
2	B	Backlog work from previous periods to be scheduled before scheduling new jobs with normal priority.
3	N	Normal priority(default).
4	D	Delay scheduling the part.
5	H	Hold schedule(part not to be included in schedule, but will be flagged as pending work in the file. This may arise due to material shortages or other causes).

FIGURE 4.3 PRIORITY CODES FOR SCHEDULING

first. While scheduling consideration is given to standard or estimated time values, shop efficiency, scrap and transit time between operations. The manufacturing time for the work order covered during a schedule is estimated using the formula[33],

$$\frac{[(\text{NO OF MOVES})*\text{TRANSIT TIME}+(\text{TOTAL HRS. OF WORK/SHOP EFFY.})]}{\text{HOURS AVAILABLE PER DAY}} = \text{NO. OF DAYS REQUIRED}$$

The work scheduled is then sent to the shop for processing and feedback is received on completed work. The shop schedule is shown in Figure 4.4.

The release of work can be controlled by either reducing its priority or by delaying its release date. The effect of lowering the priority but keeping the original release date is effective in overloaded conditions but this effect is reduced if underload occur. This method allows the user flexibility to find the best sequence. The priority is set as normal by default in the planning phase and the user has the option of changing it in the scheduling phase. It is advised that scheduling never be done for 100% of capacity. Full shop loading causes more scheduling systems to fail than any other factor. This is because if all available work center hours are scheduled with known orders, then any emergency orders or breakdowns will require an entire restructuring of the schedule making the initial schedule meaningless.

ARGO MATERIAL HANDLING SYSTEM LTD.

SHOP SCHEDULE FOR *dd/mm/yy* Page _ of _

PLAN PERIOD *dd/mm/yy* *to* *dd/mm/yy* **Work center : A01 SHEAR**

PART NUMBER	OPN. #	QTY.	ESTIMATED TIME(HRS)	ACTUAL TIME(HRS)	ACTUAL QUANTITY	OPERATOR INITIALS
CFB00010	10	100	0.8	1.2	96	
CRS00010	15	150	1.4	1.0	150	
CSS00010	10	46	1.0	1.0	38	

FIGURE 4.4 SHOP SCHEDULE REPORT

The scheduling process also involves the feedback on work completed so that the schedule can be updated. Therefore, in order to gain full benefit from daily rescheduling, a prompt and accurate feedback system has been designed. This involves daily collection of data of the jobs completed: the actual time spent on the job and the actual quantity produced. This information is essential if the schedule is to be meaningful. Actual production progress is recorded and compared with the scheduled production requirements to observe current status of each part in the schedule. Expediting action is initiated to minimize delays, to remove the causes of delays and prevent their recurrence. New schedules are prepared as necessary to replace plans and schedules which have not been accomplished. Any uncompleted work is rolled over to the next schedule with a higher priority.

A total completion of the schedule signals that the work is complete and that the relevant information can be stored in the history file. An analysis of scrap allowance that need to be provided in future production runs can be obtained from the data collected regarding the production quantity planned and actual quantity accepted after inspection. Options exist for partial completion of work.

5. SYSTEMS PROCESSING MODULE

The systems processing module consists of programs designed to perform three important tasks, viz. (i) costing, (ii) management report generation and (iii) month-end processing and house keeping. The programs included in this module are listed below.

1. Costing Programs.
   - (a) Cost Inquiry.
   - (b) Shop Order Costing.
   - (c) Historical Costs and Forecasts.
2. Month-end Processing
3. Management Reports Generation.
   - (a) Performance Measurement Reports.
   - (b) Exception Reports.
   - (c) Utilization Reports.
4. Random Inventory Count Generation.
5. Initial System Data Files Setup.
6. Reorganization of Data Files.
7. Chain to Other Programs.

5.1 Costing Systems

5.1.1 Purpose of costing: Costs are defined as resources sacrificed or foregone to achieve a specific objective. Cost accounting provides data for three major purposes,viz.,:

(i) Planning and controlling routine operations.

(ii) Non-routine decisions, policy making, and long range

planning.

(iii) Inventory valuation and income determination.

Other purposes include getting a reliable basis for predicting the economic consequences of a host of decisions such as:

(i) Which products should be made? Deleted?

(ii) Should product components be manufactured or acquired outside?

(iii) What prices should be charged?

(iv) Should the proposed equipment be purchased?

(v) Should the manufacturing methods be changed?

(vi) Should the department/division be expanded?

Cost information provides management with a clear picture of the activities of the organization and hence there is the need for determining the costs as accurately as possible[10][12][21].

5.1.2 Elements of Cost

There are three major elements in the cost of a manufactured product[10][27][33]:

(i) Direct materials: All materials that are physically observable as being identified with the finished good and that may be traced to the finished good in an economically feasible manner. Examples are sheet steel and subassemblies for a material handling equipment manufacturer.

(ii) Direct labour: All labour that is physically traceable to the finished good in an economically feasible manner. Examples are the labour of machine operators and assemblers.

(iii) **Indirect manufacturing costs:** All costs other than direct materials and direct labour that are associated with the manufacturing process. Other terms describing this category include factory overhead, manufacturing overhead, and manufacturing expenses. There are two subclassification of factory overhead, viz., (a) **Variable factory overhead:** Consumable and indirect labour fall into this category. (b) **Fixed factory overhead:** Supervisory salaries, maintenance salaries, rent, insurance, taxes, and depreciation fall in this category.

5.1.2.1 Shop Overhead

Direct materials and labour may be traced to physical units worked on through material requisitions and work orders. But, by its very nature factory overhead cannot be specifically identified with physical units. Yet the making of goods would be impossible without the incurrence of such overhead costs as depreciation, material handling, janitorial services, repairs, property taxes, utilities etc.. Overhead is applied to products because of management's desire for a close approximation of costs of different products. If such product costs are to be helpful to the management for product pricing, income determination, and inventory valuation, they must be timely as well as accurate. If the purpose were to apply all actual overhead to actual production for the year, the most accurate application of overhead could be made only at the end of the year, after actual results are determined. This would be too late and hence overhead rates are computed in advance of production and actual figures used to check the predetermined overheads in the long run. The

basis for calculating overhead costs may vary from company to company. The most commonly used bases are:

(i) Direct labour hours.

(ii) Machine hours.

(iii) Direct labour cost.

(iv) Direct materials.

5.2 The Design and Implementation of the Microcomputer Based Costing System

The costing programs developed for use, as part of the capacity planning modules have been developed to feed certain information on product costs and expenses to all levels of management and to interface with a financial package. The main impetus to developing the costing programs was the need to identify manufacturing costs of products, so that product contributions can be monitored and historical records of product costs be maintained efficiently for easy comparison and forecasting purposes.

No rational economic decision can be made in any manufacturing enterprise without the use of direct costs. Conventional or traditional forms of costing, principally absorption costing, obscure the identity and sources of company profit. This can lead to decisions that reduce rather than improve profits. The standard cost of a production operation involves both the hourly cost of the process- known as the Machine Hour Rate(MHR) and the amount of time to process the product through each of these work centers- known as Production Standard(PS). The development

of MHR is largely from existing and/or estimated cost and financial data. To develop a rational set of MHR, direct costs should be traceable to and specifically identifiable with the production facilities they represent. The skills needed to do this come from finance and production managers. The MHR is part of the work center information and it is updated frequently[33].

Direct costs are required when estimating the contribution from an offered price and/or to assist in establishing prices for products. These direct costs, as previously seen, have three major components, viz., (i)Direct labour costs, (ii)Direct material costs, and (iii)Indirect product costs - overhead costs. The objective of the costing programs is to accurately establish these costs.

It is usual to compute the cost of a product as shown below:

MANUFACTURED COST = DIRECT MATERIAL + DIRECT LABOUR + SHOP OVERHEAD

SELLING PRICE = MANUFACTURED COST + ADMN. COSTS + SELLING COSTS + INCOME TAXES + SALES TAXES + PROFIT MARKUP

The flow chart for the programs designed is shown in Figure 5.1 and the procedure is explained below.

The input to the costing program is obtained from the completed shop schedule file. This file will contain the information regarding the part,

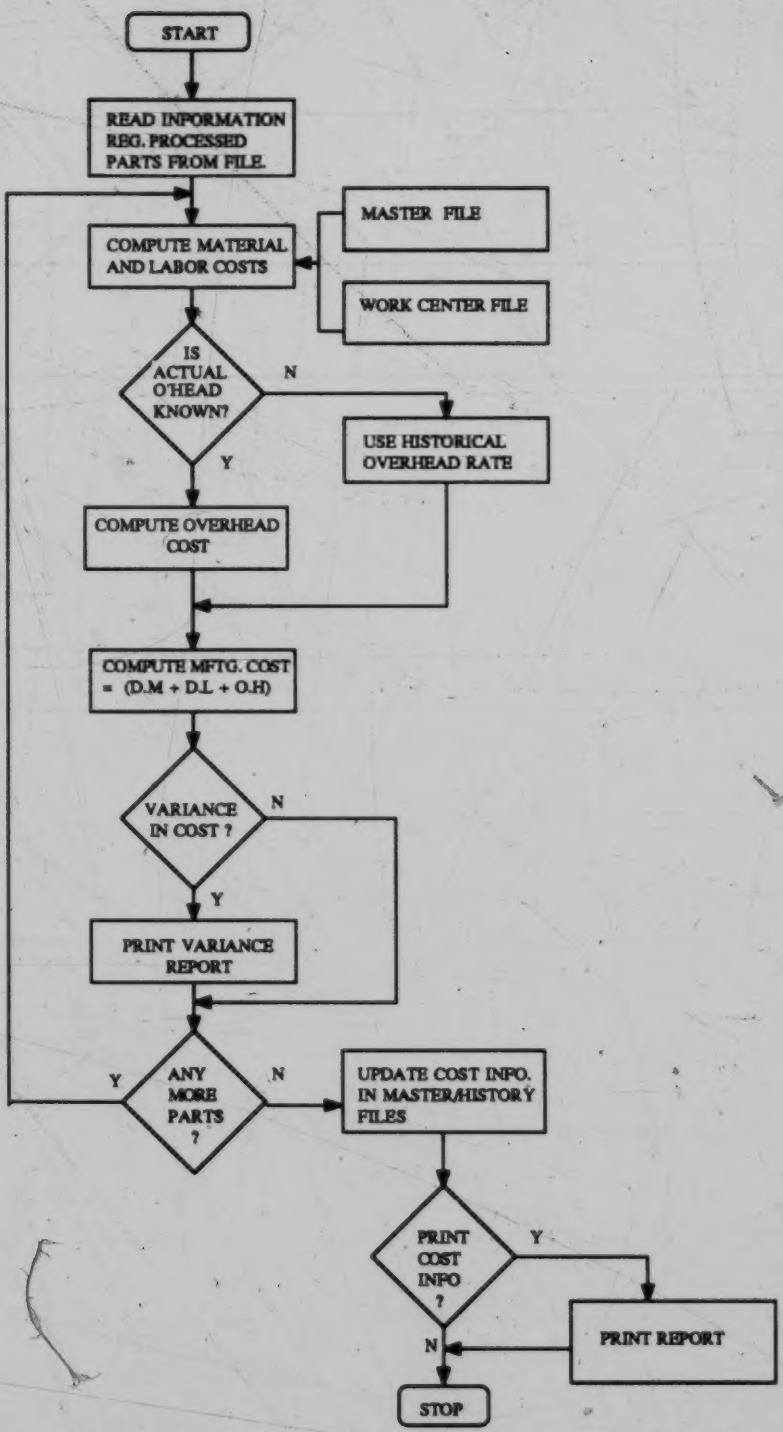


FIGURE 5.1 FLOWCHART FOR COSTING PROGRAMS

the quantity produced and the time taken to produce them. The costing programs will then compute the direct material, direct labour and overhead costs as follows.

Direct labour costs: As defined earlier these are the costs of processing the product(s) or order(s) through all the operational steps. Each operation has its own labour rates and machine hour rates -MHR, i.e., the direct costs per hour incurred in the running of the machine or work center. The starting point in the development of the labour costs is the determination as to how the product will be made. The overall process must be defined and a sound method developed for each operation. An appropriate labour measurement technique, say, time study is then employed to measure the standard time T. If the operator efficiency(η) is known then an output standard time T_o ($T_o = T / \eta$) can be determined. These requirements have been taken care of in the pre-production phase and the machine information, operations sequence information are maintained in the respective data bases. The product of the MHR and the production standard, totalled over all the operations result in the total direct labour cost[6][12][27], as can be seen from the following equation.

$$C_L = \sum_{i=1}^{n} (T_{oi} \times MHR_i), \text{ where}$$

T_{oi} is the production output standard for operation i

MHR_i is the rate applicable for operation i

n is the number of operations in the process.

A simple illustration is shown below in Table 5-1. from which it can be noted that the direct labour cost for part CFB00010 is $7.37.

Table 5-1
Manufacturing summary for Part CFB00010

Operation	Production output standard/unit(mins)	Labour rate per hour($)	Costs
10 Cutting	5	10.0	5X10.0/60= 0.83
20 Drilling	15	11.5	15X11.5/60= 2.88
30 Finishing	20	11.0	20X11.0/60= 3.66

$$C_L = \sum_{i=1}^{n} (T_{oi} \times MHR_i) = 0.83 + 2.88 + 3.66 = \$7.37$$

Direct materials: The material content of a product depends upon its configuration. Decisions made regarding the product's form, features, and such operating characteristics as weight and strength will determine what kind of materials will be used and in what quantities. Material quantities will also depend on the production process employed as there may be losses due to rejection.

The unit material cost can be obtained from purchase invoices and the actual material consumed can be obtained from material requisition summary lists to arrive at unit direct material cost. A simple illustration is shown in Table 5-2.

Overhead costs: These are the non material costs and are usually forecasted from historical records. The arrival of a specific overhead rate for a period requires a projected production volume. It is usual to compute the actual overhead cost incurred after the period is over. For

Table 5-2
Direct Material Requisition Summary .

Requisition number	Job no.	Dept. no.	Amount ($)	Job Order sub total($)
501	AR011405	26	32.00	
502	AR011405	27	51.00	83.00
503	AR011505	26	204.00	204.00
504	AR051605	28	19.00	
505	AR051605	32	101.00	120.00
.	.	.	.	.

example, if the factory is expected to operate efficiently at a volume of 16000 direct labour hours a month and management has estimated that cost using this volume, the factory overhead will be $96000 a month, the overhead rate will therefore be 96000/16000 = $6/Hr.

The sum of the labour, material and overhead cost gives the manufactured cost. Administrative and selling expenses are then apportioned to products based on labour hours expended. These expenses when added to the manufactured cost gives the factory cost less taxes[10][27]. It is this information that is made available to the user. A markup for profit can be made to arrive at the selling price. A sample output is shown in Table 5-3.

Apart from the calculation of direct labour, material and overhead costs for each product the costing programs also can project a moving average of historical costs for cost control purposes.

Once a work schedule is completed the information regarding what

Table 5-3
Cost Summary for the Month of _____

Part number	Qty.	Matl. cost	Labor cost	Overhead cost	Unit mftg. cost	Unit hist. cost
CFB00010	100	400.00	80.00	50.00	5.30	5.15
SBR00100	25	325.00	140.00	60.00	21.00	20.15
ALW01000	4	600.00	150.00	50.00	200.00	200.00
.	.	.	.	.	.	.

products were produced, on which facilities, the quantity, and the processing time are filed in the history file.

The costing programs can access this information and based on user input for administrative, selling expenses, and taxes, will be able to compute fairly accurately the actual costs and the components of actual costs.

5.3 Housekeeping and Month-end Processing

It is essential that periodical purging and updating of databases be done so that data can be efficiently handled. This is the function of the house keeping and month-end processing program in the Systems processing module. The month-end processing does the function of identifying parts completed in the shopload file, and transferring the information to the production history file. The cost and time estimates may, if the user wishes, be updated if large variances are observed over a time period. The programs setup in the MRP and CRP are designed to maintain only 13 months information(current month and last 12 months). Recent advances in

file handling includes the availability of low cost software that can perform the task of archival and retrieval of data files. They essentially compact and encrypt the files thereby reducing the size drastically. These advances will make it possible to maintain a longer period of historical records. A five year history would probably be desirable.

The programs of both MRP and CRP are written in the BASIC language. The efficient use of file space was achieved by designing the data file formats to reduce redundancy[4][7]. This was achieved by employing pointers, which are the links between files relating information corresponding to any part in the part master file. Since it is impossible to input data in an ordered sequence the files have to be rearranged in a logical sequence so that the search time is reduced. Housekeeping functions are to periodically reorganize these data files. The reorganization of RTINDEX.DAT(route index file) and OPSEQ.DAT (operations sequence file) files used in capacity planning is shown before and after reorganization in Figure 5.2 and Figure 5.3. The index file contains the part number and the pointer which refers to the location in the operation sequence file where the operations sequence is stored. The reorganization removes unused records and rearranges the records logically as shown.

Knowledge of the time required to accomplish work is a vital part of a production control system. For scheduling to use these standards effectively these files have to be updated periodically, so that the relationships between standard and actual time are known. These

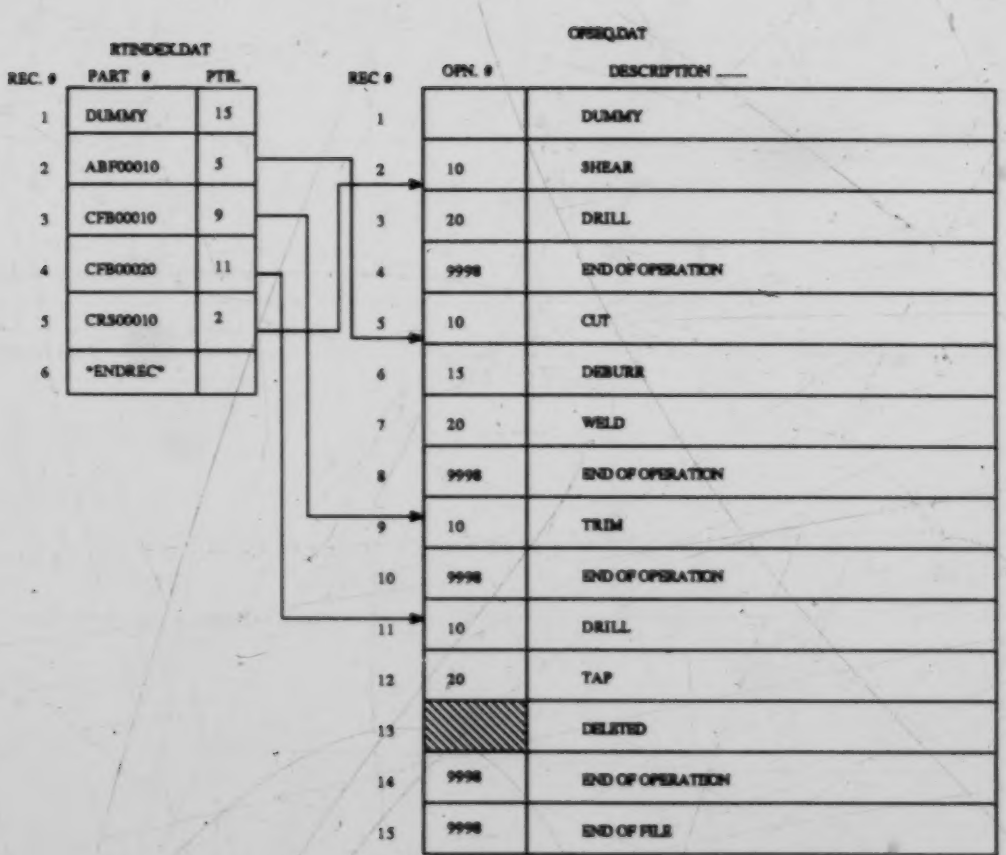


FIGURE 5.2 FILES BEFORE REORGANIZATION

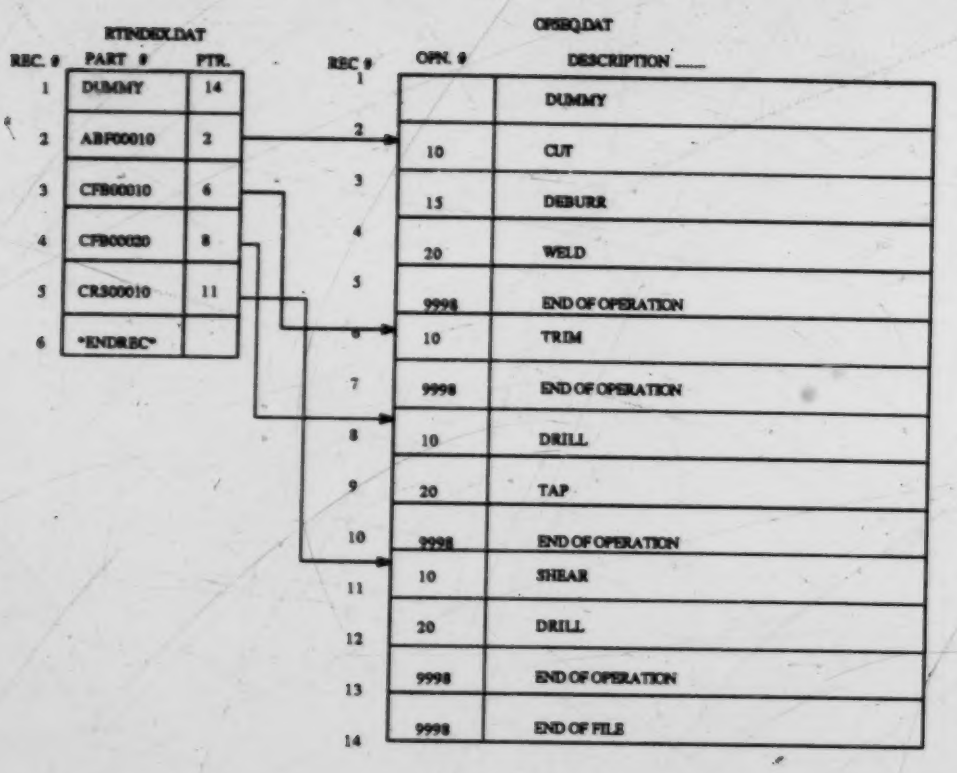


FIGURE 5.3 FILES AFTER REORGANIZATION

relationships form the basis for a more realistic production control function in the future production runs. The month-end processing also summarizes data that forms the basis for developing reports to the management that is described in the next chapter.

6. INTERFACING FINANCIAL PACKAGE AND MANAGERIAL REPORTS GENERATION

6.1 Interfacing Financial Package

As previously discussed the costing programs developed are intended to keep track of cost information of products and are not designed to carry out the accounting functions. There are many commercial software packages available to do the accounting function. Some of the packages have modules that can do a limited amount of job costing. However, the input requirements of the modules may be different from the file formats that are used in the costing programs developed in the CRP. Moreover, most of the commercial software packages available are in compiled form, and any attempt to modify them to suit the existing format may prove to be expensive. With this scenario in mind, the best solution is to develop a stand-alone program that will convert the data files into a format readable by the commercial accounting package. This work of selecting a software package and developing the interfacing program will be done by a Graduate student as part of a M.Eng. project. For integration with the designed micro-computer based production and inventory control system, two software packages, viz., **BEDFORD** and **ACCOUNTMATE** seem to be suitable.

The success or failure of any system depends on its capability to forewarn the decision makers of variations from plan. A computerized system is usually able to reduce the time gap and can present the decision makers with useful information to measure performance and observe deviations from targets.

6.2 Performance Measurement Report

The term productivity is used to measure actual output against the standard expected. Productivity deals with time and not costs directly. It is essential that management is made aware of the shop status so that any persisting problem can be tackled more efficiently. Work center performance reports and plant performance reports have been designed for this purpose. The sample reports are shown in Figure 6.1 and Figure 6.2. Clock hours are actual hours spent on the job. Non-chargeable hours are unproductive hours due breakdowns etc. Earned standard hours are the actual standard hours allocated for the job based on standard time estimates. With a known standard time(hence the earned standard hours), and the workcenter rates, any variance between clock hours and earned standard hours denote the potential gain/loss (contribution) of the workcenter.

6.3 Exception Reports

The reports designed for this purpose are intended to reflect large changes over successive planning periods. Delivery delays are also classified under this category as the objective is to meet due dates. The report formats are presented in Figure 6.3 and Figure 6.4.

6.4 Utilization Reports

The efficient utilization of facilities is of extreme concern to management and the utilization of facilities will help management to develop strategies for off-loading sub assemblies, or conduct new product research and the like. The report format is shown in Figure 6.5.

ARGO MATERIAL HANDLING SYSTEM LTD.
PLANT PRODUCTIVITY REPORT

Page _ of _

MONTH ENDING : *dd/mm/yy*

WORK CENTER #	CLOCK HRS.	NON CHARGEABLE HRS.	CHARGEABLE HRS.	EARNED STD.HRS.	PRODUCTIVITY
A01	160.00	20.00	140.00	133.00	95.0 %
A10	160.00	10.00	150.00	164.00	109.0 %
B20	160.00	0	160.00	154.00	96.0 %
B99	160.00	40.00	120.00	106.00	88.0 %
C99	160.00	60.00	100.00	75.00	75.0 %
TOTALS	800.0	130.0	670.0	632.0	94.0 %

FIGURE 6.1 PLANT PRODUCTIVITY REPORT

ARGO MATERIAL HANDLING SYSTEM LTD.

PRODUCTION CENTER PERFORMANCE REPORT Page _ of _

MONTH ENDING : PRODUCTION CENTER : A10 *dd/mm/yy*

JOB #	CLOCK HRS.	EARNED STD.HRS.	VARIANCE HRS.	CONTRIBUTION GAIN(LOSS) $
0010	8.00	6.00	(2.00)	(82.94)
0015	8.00	7.00	(1.00)	(41.47)
0100	8.00	9.00	1.00	41.47
0110	8.00	8.00	0	0
0200	8.00	5.00	(3.00)	(121.41)
TOTALS	**40.0**	**35.0**	**(5.0)**	**(207.35)**

PRODUCTIVITY = EARNED HRS. / ACTUAL HRS. = 35 / 40 = 87.5 %

FIGURE 6.2 PRODUCTION CENTER PERFORMANCE REPORT

ARGO MATERIAL HANDLING SYSTEM LTD.
PRODUCT DELIVERY SCHEDULES Page _ of _

MONTH ENDING : dd/mm/yy

PART #	CUSTOMER	VALUE ($)	DELIVERY DATE	
			PROMISED	ACTUAL
FDL16200	U O A	4000.00	*04/15/88*	*04/20/88*
FDL16200	N A I T	3850.00	*04/10/88*	*04/10/88*
FDL15400	S A F E W A Y	5125.00	*05/12/88*	*05/15/88*

FIGURE 6.4 PRODUCT DELIVERY SCHEDULE REPORT

ARGO MATERIAL HANDLING SYSTEM LTD.

PRODUCT COST REPORT

Page _ of _

MONTH ENDING : *dd/mm/yy*

PART #	CURRENT COST $	LAST RUN COST $	SIX MONTH AVG. COST $
ALP00100	600.00	550.00	574.00
ADW00100	980.50	1000.00	1050.00

FIGURE 6.3 PRODUCT COST REPORT

ARGO MATERIAL HANDLING SYSTEM LTD.
PLANT UTILIZATION REPORT Page _ of _

MONTH ENDING : *dd/mm/yy*

WORK CENTER #	ACTUAL HRS.	SCHEDULED HRS.	UTILIZATION (%)
A01	160.00	150.00	93.75
A10	160.00	40.00	25.00
B20	120.00	100.00	83.33
B99	100.00	100.00	100.0
C99	80.00	75.00	93.75

FIGURE 6.5 PLANT UTILIZATION REPORT

The use of these reports will identify bottlenecks and thus facilitate in improving the overall planning and co-ordinating of the various departments.

7. IMPLEMENTATION OF THE SYSTEM

This thesis involves the development and implementation of a complete computerized production and inventory control system at Argo Material Handling Ltd. This study is the second of a two-part research project which involved the design of a total material and capacity requirements planning system. The first part of this chapter is devoted to a general discussion, while the second suggests recommendations for implementation.

7.1 Implementation Factors

Although there are many factors that contribute to a successful implementation, the following discussion can serve as a guide to future installations.

7.1.1 Management Support

The first requirement for any successful implementation is to have the full support and active commitment of top management. In most organizations, the main obstacle to a successful system lies not in the technical areas(hardware and software), but in the people involved - their attitudes, interests, and commitment towards the system. It is well known that seeking top management support and approval is a time consuming task. Often this means endless presentations, studies and meetings, but this is an inevitable and vital step to a successful implementation because of the following reasons:

(i) A properly designed and run computerized production and inventory planning and control system will change the entire

operation of the organization. It means a redistribution of powers within an organization. People do not like to lose the controls that they have acquired over the years and conflicts of interest may occur.

(ii) Implementation of a new system is costly. In addition to hardware and software costs, other costs such as re-hiring, training, and consulting will be involved.

(iii) The time needed for installation and full utilization can be lengthy. Typical time requirement for an average system like this may exceed one year depending on the status of the present practices, availability of data records, and co-operation of management. During this time span, a successful implementation requires the continual support and a certain commitment to implementation from everyone in the organization.

7.1.2 Data Acquisition

During implementation, the most demanding and time consuming task is establishing the accuracy and integrity of the databases. Inaccurate and obsolete bill of materials records can hinder the computerization process considerably. When this happens, one cannot solely rely on information available on the files and a follow up is required to update the files as quickly as possible. Obsolete files are a major cause for people getting dis-illusioned with computer systems when they are installed for the first time in the organization. The system also requires fairly accurate estimates for production standards if the schedules developed

are to be realistic.

7.1.3 Education and Training

Before and after implementation, the company has to provide an essential education and training program to all its staff. The key people that will benefit most from such a program are those who rely heavily on the system's operation and output. There are basically four areas to be covered in an education program. They are:

(i) Why does the company need such a new system ?

(ii) How will the new system affect employee's day-to-day activities ?

(iii) Why is the support of all personnel so critical to the success of the system ?

(iv) The system is here to help, and is not a threat to anyone's job.

The benefit of such a program is that it should clarify the doubts of the employees. Not everyone in the organization needs to go through the same level of detail and sophistication.

As with most new installations, certain new skills are required in running the system. This means retraining of some of the existing staff and sometimes recruitment of new employees. The existing organization structure may have to be changed to accommodate the new system. Management support is needed for a smooth transition.

7.1.4 Personnel Turnover

One of the more common factors contributing to the failure of the system is high employee turnover, especially those involved in the data processing areas. It is not uncommon that the people who initially designed and installed the system might no longer be with the company to complete the implementation. Personnel turnover is something that is not fully controllable by the management, however, a certain degree of influence can be exercised over the timing of the turnover. When an employee's departure is affirmed, the company must act quickly to find a suitable replacement, either by hiring or shuffling some of the other staff. If this is done swiftly, then adequate time will be given to the new employee to follow up the duties and responsibilities of the "would be" ex-employee before he or she departs.

7.2 Implementation at Argo Material Handling System Ltd.

A microcomputer-based capacity requirements planning(CRP) system for small manufacturers has been partially tested at Argo Material Handling Ltd., a small manufacturing company located in the northwest industrial area of Edmonton. The company specializes in the design and manufacture of a number of material handling equipment such as dock levellers, elevating docks, door seals, and wheel-chair lifts. The result is an improvement in the accuracy and reliability of the inventory records and easier planning and control of shop schedules. The company is in the process of computerizing the design function into the system.

Due to the nature of the business at Argo, it is not uncommon to

receive orders from a customer that are only slightly different from the many standard designs that the company usually produces. This means new drawings have to be drawn, a bill of materials prepared, and the process plan finalized. This is a time consuming activity and often the job is started by word-of-mouth instructions so that the delivery schedule is met.

The inventory master files and the bill of materials have been entered for about 2000 stock items. However the operations sequence information has been entered for only about 1000 items. The production standards presently available will have to be updated, if the schedule is to be realistic.

The order processing is to be computerized soon with the manual follow up to monitor the system. The MRP system will not be available until then. To get around this hurdle, a shop work order release program has been designed which overrides the MRP and calculates the requirements directly from the bill of materials and prepares a sorted list of work to be routed to the shop. This will enable the collection of some recent operational times that can then be used in future runs.

7.3 Recommendations

The CRP application software was developed on the IBM Personnel Computer using the BASIC computer language. The program source code and data file format are available for making modifications or future enhancements to the system. During the implementation process many

difficulties were encountered and the following is a list of recommendations for implementing similar systems:

(i) The MRP which feeds the net requirements information to the CRP will be accurate only if the part master files are complete and up to date. During the time spent for updating the files, the MRP may be overridden and the shop schedule can be directly prepared from the bill of materials relationships and operations sequence information without any consideration for capacity limits. This will give a chance to collect some time estimates as well.

(ii) Frequent changes to drawings is a time consuming task to be done manually. If the system can be interfaced with a computerized drafting package like Autocad, then interfacing programs can be written to down load a bill of materials directly to the system when a new drawing is released. Thus, there will be only one system in operation and there will be no confusion in the shop.

(iii) Program speed. The CRP application programs are written in IBM's interpreter BASIC language. These can be very easily compiled for faster execution.

(iv) Storage medium. The amount of data that can be stored on one double sided double density 360K diskette is approximately 1000 stock item records. Since the shop handles a large database a hard disk for data storage is highly recommended.

(v) Multi-user environment. The present CRP application software can be run in single-user's mode. This means only one person

can use the system at a time. Recent microcomputer systems are capable of executing multiple applications concurrently. Thus, future development of the CRP package should allow for multi-user environment.

(vi) The incorporation of a decision support system(DSS) in the planning environment is recommended. A DSS can evolve as the decision maker learns more about the problem to be solved and moreover, a DSS can be developed by non-data processing professionals. The decision to develop one's own DSS, or to install a vendor-supplied system has to be carefully evaluated. It should be noted that certain industries and organizations are better suited than others to the use of packaged systems. If a packaged system provides, or can be modified to provide, management's information needs, a great deal of time and developing effort can be saved. Other factors to consider include the availability and skill of in-house personnel, the commitment and investment in an existing system, and the extent to which the organization is willing to modify its procedures to conform to the packaged system.

8. STRATEGIC PLANNING

8.1 Strategic Planning Fundamentals

A plan is a predetermined course of action. It represents goals and activities necessary to achieve those goals. Control is the activity that measures deviations from planned performance and initiates corrective action. Planning is an ongoing organizational function that provides the framework for operational activities and decision making. The organizational mission is translated into operational objectives through an organizational hierarchy of planning activities. There is planning in organizations even though there may not be a formal operational plan; however, informal planning is usually inconsistent and incomplete. The reasons for formal organizational planning are to focus the energies and activities of the plans of the subareas and individuals within the organization, and to remove ambiguities about what the organization should do. The formal plan not only guides activities; it provides a basis for evaluating results[15][16]. Four conceptual levels of planning in an organization can be identified, differing in the organizational level of responsibility identified, the scope of planning issues addressed, and the planning horizon(sometimes, the third and fourth levels are considered as one level). The typical levels in the hierarchy of planning[16] are shown in Figure 8.1.

8.2 Need for Long Range Planning(LRP)

The need and the benefit that can accrue from planning can be easily demonstrated through a simple questionnaire. Prepare a short list of

questions that are believed to be vital for the firm's future. Ask each executive who has responsibility for high level decision making to answer

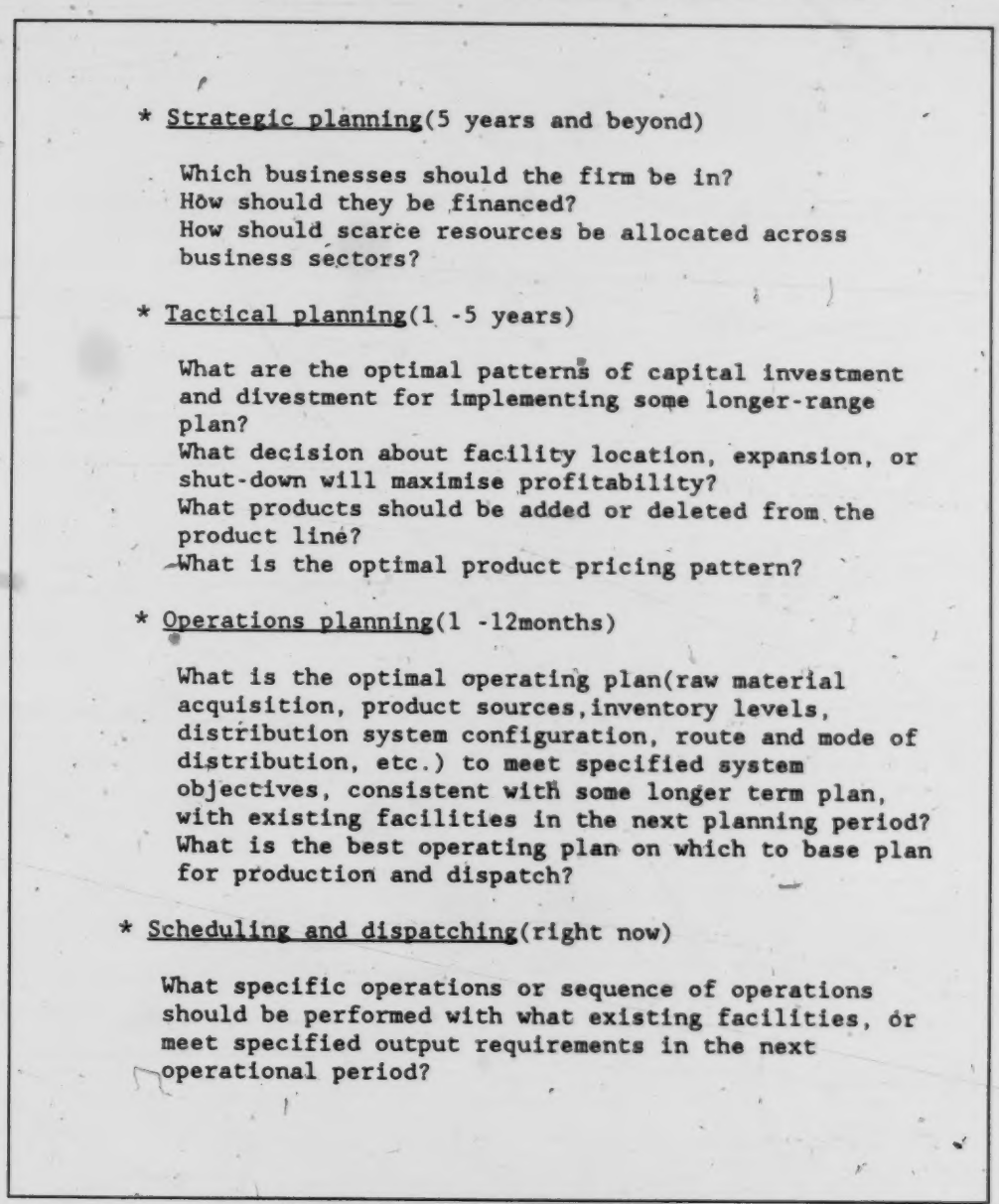

* Strategic planning(5 years and beyond)
Which businesses should the firm be in?
How should they be financed?
How should scarce resources be allocated across business sectors?
* Tactical planning(1 -5 years)
What are the optimal patterns of capital investment and divestment for implementing some longer-range plan?
What decision about facility location, expansion, or shut-down will maximise profitability?
What products should be added or deleted from the product line?
What is the optimal product pricing pattern?
* Operations planning(1 -12months)
What is the optimal operating plan(raw material acquisition, product sources,inventory levels, distribution system configuration, route and mode of distribution, etc.) to meet specified system objectives, consistent with some longer term plan, with existing facilities in the next planning period?
What is the best operating plan on which to base plan for production and dispatch?
* Scheduling and dispatching(right now)
What specific operations or sequence of operations should be performed with what existing facilities, or meet specified output requirements in the next operational period?

FIGURE 8.1 HIERARCHY OF PLANNING

them and compare the answers. They are almost certain to disagree. This simple device may help explain why some departments in the company have been working at cross-purposes. It may give a clue to the real reason behind personality conflicts, and uncover poor communication within the firm. A few key questions that could be asked are presented below, even though these are by no means final and exhaustive.

(i) What business is the company in ?

(ii) Where is the market ? Who are the customers ?

(iii) What business should the company be doing in five years from now ?

(iv) What immediate problems must be solved ? Which ones are so critical that their solution, in one way or other, will have an important influence on the future of the firm?

(v) What should the return on investment be - three, five, ten years from now ?

(vi) How big should the company be in five or ten years ?

(vii) What should be the market share of the company's products in the market - three, five , ten years from now ?

(viii) What means should be used to grow - acquisition, merger, R&D, improved marketing ?

(ix) How should the company be financed ?

In most firms where formal LRP is unknown, the results of this questionnaire will do more to show the need for LRP than any other persuasive argument that can be made.

8.3 Methods for Strategic Planning

In finding and solving a problem a decision maker faces a myriad of decision cycles. What is the problem and what is the cause of the problem?. What additional data is needed, and how should the solution be implemented?. Each of these major steps in solving a problem involves the solution of sub problems, and many decisions have to be made[22][32].

The models developed in the area of planning can be classified as:

(i) **Conceptual**. A model describing the planning process in terms of factors both internal and external to the planning unit.

(ii) **Behavioral**. A model describing the planning process in terms of a set of inter-related variables.

(iii) **Mathematical**. A model describing the planning process in terms of variables quantified to scale.

The problem structure of these models can be generalized as:

(i) **Definition of scope usually on a time frame.**

(ii) **Explicit provision for evaluating discrete/parametric variations in model inputs.**

(iii) **Model structure should be such that direct access to the model and database are possible for most effective use of the approach.**

8.4 Data for Planning Purposes

The sources of planning data are internal data organized and processed for planning purposes, and external data from various sources and environmental scanning[14]. The internal data reflects the historical performance of the organization. It is usually very accessible, and its

accuracy known. However, it should not be the sole input to the planning process because external factors may invalidate historical performance for projections. External data can be obtained from traditional sources such as published reports, government documents, or services that provide industry data. Some trade associations provide industry data and projections. External data can also be obtained from data banks covering a wide variety of economic activity. Another alternative and the most important one, for obtaining planning data is the use of environmental scanning techniques.

8.5 Requirements of a Strategic Plan

A planning model is a method for structuring, manipulating, and communicating future plans. The model describes the process by which the plans are developed from input data and internal calculations[20][23]. The model should provide:

(i) A format for presenting the result from processing the model.

(ii) A set of input data.

(iii) A set of processing statements(formulas, logic etc.).

As described earlier a strategic plan is a long term plan on which the future of the organization rests. The strategic plan involves the identification and communication of the following:

(i) Mission	-	A broad statement of the purpose of the organization.
(ii) Goals	-	A general statement of what is to be accomplished.
(iii) Strategies	-	A general approach to achieve goals.

(iv) Objectives - A statement of measurable results to be achieved.

(v) Plans and budgets- A guideline for preparing budgets for sub-plans.

(vi) Policy - Limits to acceptable behaviour, express ethical and moral values, decision limits, and standards.

(vii) Time frame - The time period under consideration.

8.6 Strategic Planning For Argo Material Handling System Limited.

Argo is a small manufacturer of material handling equipment. The company's main area of strength is in the design and production of these products. The company's existing product lines are dock levellers, elevating docks, handicapped lifts and dock seals, and these are sold in Canada, United States, and other foreign countries.

The management of the company has shown keen interest in streamlining the operations of the organization and is in the process of implementing a computerized Production, Inventory control and Planning System, for efficient use of resources. The analysis of the company's past sales indicate that sales have stagnated and have not grown as the management expected. This is mainly due to the present product lines, which due to the competition have a strong position only in regional markets.

Figure 8.2 shows the position of the company and the management goal to be reached. This will mean that a new product has to be introduced in a market with a large potential. Market research conducted through dealers

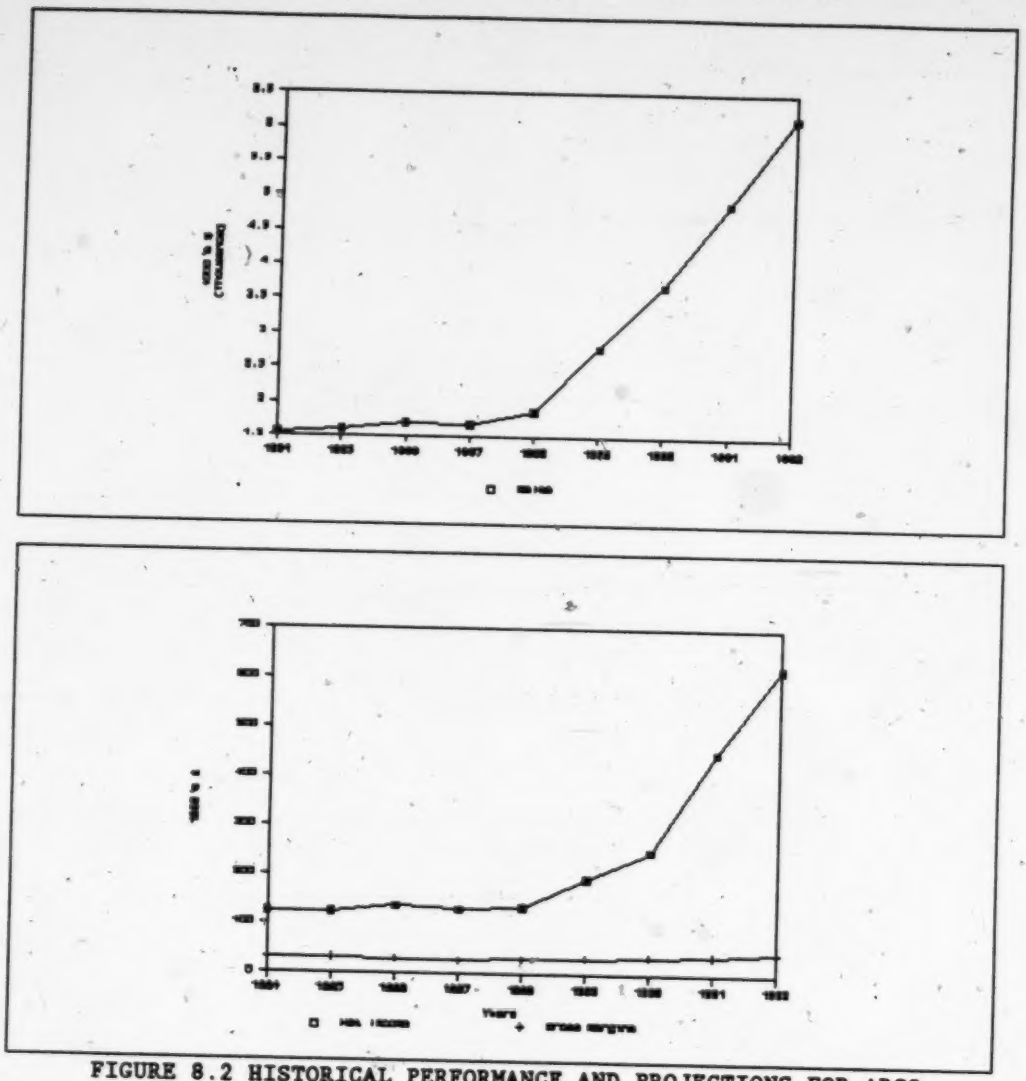


FIGURE 8.2 HISTORICAL PERFORMANCE AND PROJECTIONS FOR ARGO

and industry data show that the United States market for handicapped lifts to be promising.The company's main product lines and their estimated market position over the next five years is shown in Figure 8.3. The products can be analyzed on a product position comparison grid as shown in Figure 8.4. The grid position reveals that

the Canadian market is very price competitive and hence sales are dominated by regional manufacturers as transportation costs can be a large factor. It is obvious that there is a very large potential to enter into the United States market for handicapped lifts, especially in the west. The scope for expansion in the United States is strengthened by the fact that at present the United States manufacturers of comparable products are situated in the east, and hence Argo could be very price competitive. Based on the preliminary analysis the LRP objectives for Argo can be stated as,

Mission: "To diversify our product lines so as to minimize the dependence on any one product line completely for existence and growth".

The long range objectives set to fulfill this mission statement are:

(i) Argo's basic business objective shall be to manufacture and market products required by customers for areas of their home, office, or institutions that can be manufactured through the processes within our technological scope.

(ii) Argo shall distribute products to the above customer groups in Canada, United States, and other foreign countries.

(iii) The firm shall strengthen its present sales and distribution facilities and shall immediately develop or expand the facilities to achieve the market coverage.

(iv) The firm shall maintain a high standard of customer and product service.

Year	1	2	3	4	5
Canadian					
Dock Levellers	4600	5000	5500	6000	6500
Argo(units)	220	220	220	220	220
% Share	4.8	4.4	4.0	3.7	3.5
Elevating Docks	950	1000	1050	1100	1150
Argo(units)	60	70	80	90	100
% Share	6.3	7.0	7.6	8.2	8.7
Handicapped Lifts	300	320	340	360	400
Argo(units)	15	17	20	25	30
% Share	5.0	5.3	5.9	6.9	7.5
Door Seals	14300	15000	15500	15800	16000
Argo(units)	260	350	380	425	450
% Share	2.1	2.3	2.5	2.7	2.8
United States Expansion					
Handicapped Lifts	200	575	700	1300	2200
Total Sales(Mil.$)	1.871	2.789	3.703	4.830	6.150

FIGURE 8.3 MARKET GROWTH FOR ARGO

(v) Within a five year period, our objective shall be to double our present rate of product development by means of internal development.

(vi) Our rate of growth objective shall be to increase our sales volume by an average of 35% annually, maintaining a 45% gross margin on products.

(vii) Our major objective in terms of direction of growth shall be to expand present product lines and acquire or develop new products within our selected markets.

(viii) As a method for growth, our objective shall be to acquire or develop products utilizing our present manufacturing facility and technical skills. Entry into frontier fields except as related to our present technology should be avoided.

		SALES	PRICE	QUALITY	MARGINS	U.S. MARKET
	ARGO	REGIONAL	COMPE-TITIVE	HIGH	35% LOW	FAIR POT.
D L	FEW MAJOR COMPE-TITORS	SOME NATIONAL	COMPE-TITIVE	COMPA-RABLE	-	-
	ARGO	REGIONAL	COMPE-TITIVE	HIGH	45% FAIR	FAIR POT.
E D	MANY COMPE-TITORS	REGIONAL	COMPE-TITIVE	LOW	-	-
	ARGO	REGIONAL	COMPE-TITIVE	HIGH	55% HIGH	LARGE POTENTIAL
H L	COMPE-TITORS	REGIONAL	COMPE-TITIVE	FAIR	-	-

DL- DOCK LEVELLER ED- ELEVATING DOCK HL- HANDICAP LIFTS

FIGURE 8.4 PRODUCT POSITION MATRIX

(ix) The firm shall attempt to meet the above objectives within the existing plant areas. If new facilities are required, they shall be built on a de-centralized regional basis. Capital equipment shall be added only for programs directly supporting these objectives, and then only if it will pay out within two years.

(x) Within five years, our objective shall be to recruit and train sufficient management and technical personnel to back up the present management group in depth and to support the growth of the firm. Special emphasis shall be placed on the development of the marketing capabilities of the firm.

8.6.1 Strategic Plan Overview

(i) **Argo's position** : The gross margins on existing products are not high. Argo has established a good position within the market it serves.

(ii) **Environment** : The size of the United States market for elevator products is very attractive. United States federal law requires all schools and public funded buildings to provide access to handicapped lifts.

(iii) **Objective** : The company proposes to improve its overall market, technology, and quality positions.

(iv) **Strategy** : A strategy of cost reduction, price improvement, improved production scheduling and inventory control, and selective resource commitment to new products and markets will be implemented.

(v) **Programs**: Expenditure of $100,000 for equipment additions and $50,000 in additional working capital are required.

(vi) **Results** : These results are forecast -($ 1000's)

	1988	1989	1990	1991	1992
Sales	1870	2790	3700	4900	6150
Net income	135	194	250	450	620

8.6.2 Situation Assessment/Environment

The planning situation can be analyzed under:

(i) **Customers** - Market has diverse customer base which includes building contractors, and industrial users. Company has low position with distributors.

(ii) **Profitability** - Profit is projected to average 10% net to sales in two years time.

(iii) **Manufacturing Capacity** - Up to about 1985 the industry capacity has almost matched market demand. However, due to U.S federal laws, the market has expanded, but additions to capacity has been slow. The company will require added capacity in equipment during the forecast period to serve growth opportunities in the handicapped lift sector.

(iv) **Technology** - Substantial engineering and design effort has been devoted to the development of a technically superior product with a great profit potential.

(v) **Competition** - Primary competitors vary by segment. Major United States competitors for handicapped lifts are in the east and hence Argo should be able to acquire a greater share in the west where it is focussing its marketing efforts. Many small producers have no design capabilites.

(vi) **Segment Analysis** - Figure 8.5 shows the industry potential(in the United States), status of Argo, and the major competitors in the United States of America

8.6.3 Objectives and Goals

The following objectives and goals have been identified.

(i) **Profitability:**

Objective(s) - Maintain balanced cash position through the forecast period. Improve operating net income over long term. Maximize cash usage by maintaining tight control over receivables and

Industry Potential

Annual U.S market size	$ 220 Mils.
Annual growth rate expected	5%

Argo Status

Sales (Handicapped lifts 1988)	$ 240,000
Average sales growth(1985-88)	3%
Average sales growth expected(1988-92)	35%
Cash position -1988	Behind
Liquidity - cash category	Behind
Technology position -1988	Lead
Degree of risk predicted	Normal

Competitors in U.S	Estimated Market Share (U.S. West)
Cheney	40 %
American stairglide	25 %
National Wheelovator	10 %
Inclinator of America	10 %

FIGURE 8.5 SEGMENT ANALYSIS

inventories. Meet corporate guidelines for return on investment.

Goal(s) - Increase net income to $662,000 by 1992. Reduce number of days for receivables to 60 days and inventories to 40 days.

(ii) **Cost:**

Objective(s) - Improve cost position relative to competition. Improve utilization of existing facilities. Maintain product quality position while improving internal quality cost performance.

Goal(s) - Increase productivity(1988=100) to 140 by 1992. Maintain quality costs at 1% of sales in 1992.

(iii) **Market:**

Objective(s) - Improve position on present markets served. Increase volume and share in selected market segments (U.S-west) through

product development, capacity additions and expanded distribution. Goal(s) - Increase sales of elevating equipment in United States to $2.5 Million by 1992. Add plant capacity by investing $100,000 in new equipment. Set up assembly facilities in United States when added capacity is fully utilized.

8.6.4 Strategic Issues

The plan has to consider the following strategic issues.

(i) **Growth** - Can the company handle the proposed sales expected with the existing facility and personnel ?

(ii) **Price** - Can price levels forecasted be maintained through the forecast period without losing market share ?

(iii) **Liquidity** - Can the company maintain a balanced cash position despite the investment required to gain forecasted growth in volume and earnings ?

(iv) **Materials** - Can the company apply resources to qualify critical raw material substitutions without jeopardizing important cost improvements and product programs.

To address the strategic issues raised, the following strategies have been formulated.

(i) **Growth** - Allocate resources to add capacity, and develop new products for long term growth of sales and earnings. Reduce impact of market cycles, if any, by increasing penetration in growth segments.

(ii) **Price/Volume** - Operate at price/volume levels which will maximize

total contribution margin. Gain market share if possible, but maintain basic capability to effectively serve markets and customers on a long term basis.

(iii) **Cost and Productivity** - Utilize existing facility to fullest extent. Concentrate resource effort on cost reduction by investing in equipment and facilities to improve labour productivity, materials and process costs. Implement product standardization programs wherever possible.

(iv) **Liquidity** - Maintain balanced cash position by limiting new plant investment wherever possible. Maintain tight control over receivables, inventories, billing terms and stock availability.

(v) **Technology** - Apply new technologies to reduce product cost and to maintain superiority in product development. Seek financial support from Government agencies and technical licensing contracts.

(vi) **International** - Improve international participation by continuing to license technology.

(vii) **Human resources** - Support growth objectives by establishing program to recruit high potential professional and management personnel.

8.6.5 Programs

In order to achieve the expected results each strategic element should have programs geared towards achieving the stated goals.

1. **Strategy**: Allocate capital and personnel resources for long term growth of sales and earnings.

   (a)Strategic Element: Improve sales and distribution strength by increasing direct selling capability.

Program(s): Continue to serve dealers and contractors through sales force. Expand sales force penetration with direct purchasing end users. Use incentive programs to target sales effort. Increase Argo's contacts with architects who prepare housing development specifications.

(b)**Strategic Element**: Emphasize existing products, service and quality.

Program(s): Utilize design advantages to increase sales in residential and commercial construction markets. Maintain high quality control and enhance customer image.

(c)**Strategic Element**: Improve utilization of existing facilities. Add capacity as necessary.

Program(s): Implement two shift operations whenever market opportunities exist. Utilize existing plant capacity to maximum extent to defer new investment. Decide on timing for setting up assembly operations in the United States.

2. **Strategy**: Operate at price/volume levels which will maximize total contribution margin. Gain share if possible, but maintain basic capability to effectively serve markets on a long term basis.

(a)**Strategic Element**: Continue strong upward price focus, maintaining capability to quickly respond to market conditions.

Program(s): Raise prices and firm up terms during strong markets. Build in price escalation whenever market will permit. Follow prices down when large share losses would otherwise occur and if necessary, gain share by maintaining a high quality.

3. **Strategy**: Concentrate resource effort on improving manufacturing

productivity and costs.

Program(s): Implement a formalized, structured program to reduce scrap and rework costs. Improve production scheduling. Implement product standardization program and reduce number of specifications offered.

4. **Strategy:** Maintain balanced cash position through selective investment, limiting new plant additions, and maintaining tight control over receivables and inventories.

   (a)Strategic Element: Improve utilization of existing facilities.

   Program: Implement two shift operations whenever possible to reduce or defer capacity additions.

   (b)Strategic Element: Continue tight control over receivables and inventories.

   Program(s): Strictly enforce billing terms. Monitor inventories closely, adjusting levels for periodic changes among long and short cycle product segments. Adhere strictly to payment terms.

5. **Strategy:** Improve international participation.

   (a)Strategic Element: Utilize technology transfer to gain new licensing income.

   Program(s): Continue to license process/technology and maintain current worldwide agreements.

In order to implement these program(s) budget a certain fixed amount.

8.6.6 Financial Summary

Following the strategic plan, Argo is expected to achieve the results

shown below. ($1000's)

	1988	1989	1990	1991	1992
Total Sales	1870	2790	3700	4900	6150
Wheel-chair	240	755	1140	1850	2500
Gross Margins	766	1227	1628	2156	2706
Net Income	135	194	250	450	620
Productivity	100	110	120	130	140

In reviewing these goals of Argo, it is apparent that they are workable. In order to attain these goals, management should be able to receive and analyze the various internal and external factors speedily and take suitable actions. A **Decision Support System(DSS)** is recommended for analyzing the company and market information. The DSS design is discussed in the next chapter.

9. CONCEPTUAL MODEL FOR DECISION MAKING AND DESIGN OF A DECISION SUPPORT SYSTEM

9.1 Conceptual Model

In order to understand the various interrelations that exist in the decision making processes of an organization a conceptual model[28] is presented to describe the process as a multistage decision process. The conceptual model in its elemental form is shown in Figure 9.1.

In many cases where project selection or management decisions are made without following a formal plan based on a set of rules, the outcome of actions taken cannot be clearly explained as there will be no clear indication as to what had gone wrong in the process that led to the decision. As a concept, the model shown in Figure 9.1 is not difficult to understand. However the same cannot be said of the individual blocks that form the model, for they help drive the decision making process.

Conceptually, any problem faced by the management has a solution that is part of the **'Global set of Alternatives'**, which may or may not meet the expectations of the business. A simple screening process(rules of thumb) can eliminate alternatives that have no potential. This reduces the options to be evaluated to a **'Perceived set of Alternatives'** which have to be rigorously evaluated. Each of these perceived set of alternatives is subject both to environmental constraints and organizational constraints, and those alternatives that survive can be called **'Feasible sets of Alternatives'**. These sets can be subject to risk

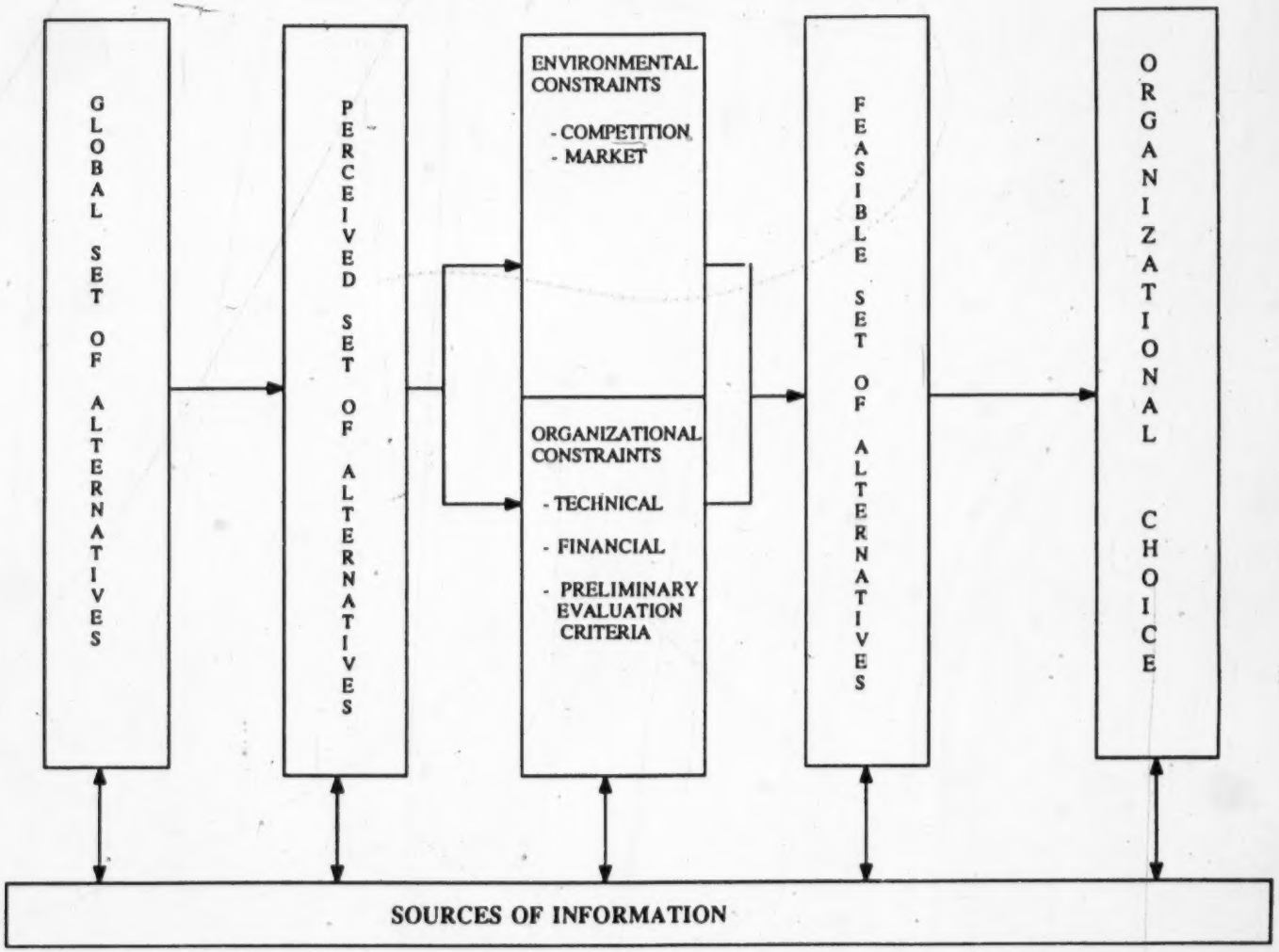


FIGURE 9.1 SCHEMATIC OF THE CONCEPTUAL MODEL

analysis or some sort of rank ordering can be done to arrive at the organizational choice. The block 'Source of Information' is the 'Data Base' of the 'Decision Support System' that is being updated continuously to be able to provide valuable information to the decision maker.

9.1.1 Model Application to Argo

This conceptual model can be applied to the decision making of a new product selection and introduction. The analysis of products manufactured by Argo and the market survey information provided reveals that the company's main product line, dock levellers, has a very low profit margin and a low possibility for improving market share. This is due to the fact that the market is very price competitive and the market segmented by regional producers. However, the United States market for handicapped lifts is very large and holds the maximum potential for growth. The organizational plan then, is to hold Argo's position in the dock leveller segment and grow in the handicapped lifts areas. The basis for this line of thinking is that even though the margins on dock levellers are not high, the product line shares a large portion of fixed costs and dock leveller parts are being shipped to the United States. The dealers and other contacts can be profitably exploited to promote the new product line.

The strategic objectives of Argo clearly states that new products should be chosen in an area closely related to the technological process with which the company is strong. Handicapped lifts can be designed and manufactured within the existing framework of company operations without

major changes.

The 'global alternatives' for Argo, then, can be thought of as a large number of products, components and spare parts in the material handling industry.

In order to eliminate many less attractive products a simple New Product Evaluation checklist and a Product Evaluation Chart have been designed (Figure 9.2 and Figure 9.3). The checklist is broken down into seven basic areas: finance, competition, sales and distribution, legal, market, production, and research and development. The checklist serves as the starting point for evaluating new product options of the company. The evaluation chart can then be completed based on the checklist and a scoring system can be employed to include weights for the various areas. The selection of a proper weighing scheme involves the use of several criteria to evaluate business opportunities. These kind of problems are termed as multi-criteria decision making problems.

The decision making consists of the clarifying of goals, the generation of alternatives, the search for information, the evaluation of alternatives and implementation and control. The kinds of issues attacked under each of the major groups is selected from what are thought to be parameters directly affecting the outcome. The selection process usually involves the following steps:

(i) Search - search for all possible attributes that can be effectively measured against a reliable bench mark.

FINANCIAL

ROI ___
Industry profit trends ___
Discount-cash flow history ___
Cash or stock requirements ___
Time to profitability ___
Dollar value potential ___
Complements LRP ___
Price competition ___
Risk ratio vs ROI ___
Cost of marketing ___

COMPETITION

Number and size ___
Company image ___
Quality ___
Product advantages ___
Price advantages ___
Personnel advantages ___
Marketing advantages ___
Ease of entry ___
Opportunity for improvement ___
Historic trends ___

SALES AND DISTRIBUTION

Cost of sales ___
Physical distribution ___
Discount factors ___
Utilizes personnel skills ___
Sales service requirements ___
Sales appeal ___
Freight factors ___
Calibre of competitive sales ___
Cost of new sales organization ___
Price factors ___

LEGAL

Patent or acquisition possibility ___
Disclaimer form accepted ___
Copyright trademark validity ___
Infringement liability ___
Option - royalty terms ___
Patent application feasibility ___

MARKET

Size and growth trend ___
Utilizes management skills ___
Uses marketing organization ___
Research costs ___
Repeat possibilities ___
Complements LRP ___
Territory restrictions ___
Seasonal aspects ___
Product design and packaging ___
Advertising - public relation costs ___

PRODUCTION

Low tool costs ___
Uses present facilities ___
Uses present labour force ___
Effect on labour relations ___
Manufacturing ___
Raw material availability ___
Inventory requirements ___
Calibre of competitive production ___
Outside purchase ratio in-plant production ___

RESEARCH AND DEVELOPMENT

Low development cost ___
Material feasibility ___
Technical rating ___
Success history - similar products ___
Development time ___
Personnel limits ___
Facilities adequate ___
Experience factors ___
Output warrants investment ___
Within risk criterion ___
Complements LRP ___

PROJECT # _____

PRODUCT _____

DATE _____

FIGURE 9.2 NEW PRODUCT EVALUATION CHECKLIST

(ii) Creation of alternatives - from the search list identify the most useful attributes.

(iii) Decision - in this phase decide on the measurement scales against which the attributes are classified as positive or

negative.

(iv) Implement - try out the selected attributes on a case that is known and evaluate the results.

EVALUATION FACTORS	POOR (0-5)	FAIR (6-7)	GOOD (8-9)	EXC. (10)	REASON FOR EVALUATION	TOTAL SCORE	WT
FINANCIAL							
MARKETING							
COMPETITION							
RESEARCH AND DEVELOPMENT							
PRODUCTION							
SALES AND DISTRIBUTION							
LEGAL							

TOTAL SCORE

PROJECT # _____

PRODUCT _____

DATE _____

FIGURE 9.3 PRELIMINARY EVALUATION CHART

In the literature multi-criteria decision models[35] are classified as:

(i) Decision outcome oriented - models based on a view that one achieves an understanding of a problem if one can predict its outcome accurately. Utility functions and decomposition techniques are examples of this approach.

(ii) Decision process oriented - models based on the concept of

understanding the process. Multi-objective linear programming(multi-parametric programming) and interval programming are examples of this approach.

Many types of evaluation models have been presented in the literature[35] that will fall under one of the following classes:

(i) Conjunctive models.

(ii) Disjunctive models.

(iii) Linear models.

(iv) Additive models.

(v) Lexicographic models.

(vi) Utility models.

(vii) Hierarchical models.

For the selection of proper attributes that comprise the major areas presented in the checklist, the hierarchical approach appears to be effective and relatively easy. This process begins with the selection of a large set of variables and progressively reducing it to a choice set capable of measuring the effectiveness of the area it represents. This process should be decided by top management personnel who have experience and can predict closely the relationship of the attributes and the probability of success. The total weighted score then will be the basis for further consideration of product choices. The product ideas that pass through this stage are the 'perceived set of alternatives'.

The next stage is the analysis of internal and external constraints. The environmental constraints involve the analysis of markets and competitor(s) strengths and weaknesses. The organizational constraints

primarily involve the technical capabilities, and financial requirement for the new product decision. In Argo's case, for its proposed expansion, the market analysis indicates that the potential for handicapped lifts in the United States is very large. Argo being a technically strong organization, the main internal constraint is identifying the source of funds for financing capacity additions required due to the new product introduction.

With this scenario, the alternatives available to Argo can be enumerated as:

(i) Discontinue some existing products to make room for the new product without any additions to existing capacity.

(ii) Maintain market share in dock levellers while promoting elevating docks and wheel chair lifts. This will involve additions to capacity.

(iii) Sub-contract some of the components, to make room for the new product and add capacity in a phased manner.

Since the management policy is to maintain current market share of products that cannot gain a greater share of the market the feasible set of alternate choices available to Argo then include:

(i) Arrange for additional funds to add to capacity.

(ii) Sub-contract certain components.

The final organizational choice may involve both of these alternatives. A continuous review will have to be done every quarter to analyze market conditions and make appropriate decisions. It is for such situations that a decision support system(DSS) will be very useful.

9.2 Decision Support System

9.2.1 DSS Defined

A DSS is a computer-based information system used to support decision making activities in situations where it is not possible or not desirable to have an automated system perform the entire decision process.

It is a support, as the decision making criteria are not fully developed in unambiguous terms.ie. the rules for deciding are not specific. A data base system with a high query language capability can be the basis of a DSS[5][17].

9.2.2 Need for DSS

Strategic information is required by management in order to formulate plans that are best for the organization[20]. There are many questions that have to be answered, like:

What are the most critical variables affecting the success of present business ?

What is the total cost associated with a project spanning different departments ?

How long can the firm wait to begin financing a major expansion program, given different confidence levels in expected interest cost to finance the program ?

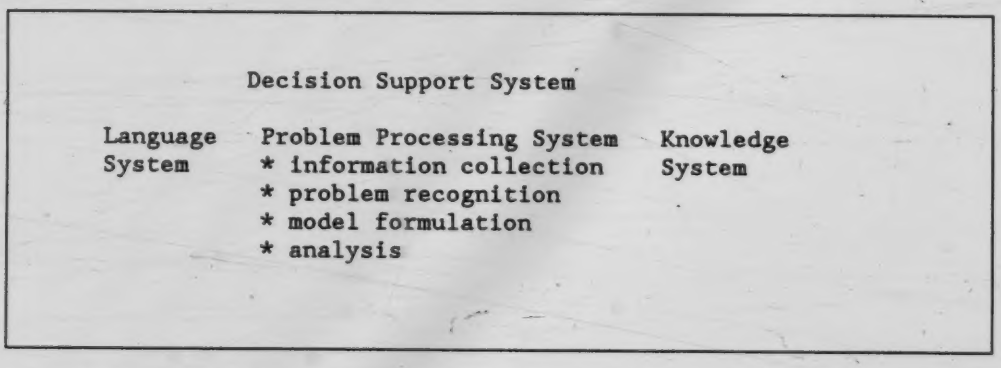
Is the equity position of the firm really increasing or decreasing due to effects of inflation ?

Which product lines are performing well, which are to be strengthened and which are to be dropped ?

Who are the competition, and how are the competitors performing ? The importance of this sort of information is well understood. When received on a timely basis the management can react to new opportunities or head-off potential problems before they materialize.

9.2.3 DSS Framework

The general DSS framework can be viewed as having three components- its Language System(LS), Knowledge System(KS), and Problem Processing System(PPS)[13][31]. A user states problems for a DSS to solve by using a language system. A DSS's knowledge system holds facts about an application area that are relevant to solving problems for that application. The problem processor accepts problems represented with the LS and utilising application-specific knowledge represented in the KS generates information for decision support. The framework is shown below.



In designing a DSS prototyping or adaptive design[25] has been one of the ways adopted by many organizations. A problem to be solved is chosen. A reliable problem solving technique is then applied to solve the problem and tested against a bench-mark. The results are analyzed and necessary modification are done to the processing model. This is useful because the

requirements of the system cannot always be predetermined.

9.2.4 DSS for Planning

In most small organizations strategic and tactical decisions are made on the basis of intuition, judgment and past experience[16][23]. In order to present valuable information to top management, the system must be broken down into integrated subsystems. The major subsystems are, Finance, Marketing, Manufacturing, Purchasing, Personnel, Accounting, R&D, and Corporate planning. Each of these sub systems will consist of different modules which may affect the performance of other subsystems. As a starting point for effective planning within a DSS environment, it is helpful to examine those factors that are capable of making/breaking an organization. These factors are called under different names as[5][9][13], critical success factors(CFS), key result areas(KRA) or strategic business units(SBU's). These factors are areas of activity that should receive constant and careful attention, and their performance measured continually as these factors support the attainment of the organization's goals and objectives.

The source of these factors depend on the structure of the industry, the competitive strategy, the industry position, and internal and external factors.

9.2.5 Steps in DSS design

In order to develop a DSS the following steps can be used as a guideline.

(i) Decide on the type of problems that are expected to be

solved.

(ii) Select appropriate models for forming part of the processing and knowledge systems.

(iii) Check and decide on input data formats.

(iv) Build data base and check integrity of data.

(v) Run the DSS with a problem and compare with known bench marks.

(vi) Update database.

(vii) Embellish problem solving model continuously.

9.2.6 Design of a DSS for Make/Buy Analysis

9.2.6.1 Data Base for a DSS

The data base of any DSS has to have up to date information that can be accessed by the processing and knowledge sub-systems[32]. For a DSS in the capacity planning area, the database should contain the following information.

DSS data base

<u>Finance information</u>

Capital structure
Outside sources of funds
Cost of outside sources of funds
Cash receipts
Cash disbursements
Other receipts and disbursements
Projected cash needs
Product cost details

<u>Marketing information</u>

Customer master file
Forecasting data and formulas
Historic data on performance
Market research data
Market research models and techniques.
Service level data
Order level data

Vendor details and capabilities

Production information
Machine capacity and utilization
Machine capabilities of producing items
Machine cost factors
Sales orders(and back orders)
Engineering data and product change/cost information
Inventory information- raw material WIP, and finished goods
Due dates, manpower requirements

A make/buy mathematical model can be incorporated in the DSS to access the data base and a decision can be made regarding which components are to be produced and which are to be sub contracted.

To identify product components that can be sub-contracted to make capacity available, a mathematical model is presented. The objective is to minimize the total production cost maintaining capacity and demand restrictions.

9.2.6.2 Mathematical Program Model for Make/Buy Analysis

The production process within a factory can be considered as a multi-stage process as shown in Figure 9.4. Each of these stages may have alternative process technology capabilities which are either in place (in-house capacity) or under consideration(farming out)(The simplest case being, each process having only 2 technological choices, viz., in-house and only one vendor). The purpose of the model is to predict the impact of the alternative process technology choices on both product unit costs and related measures of manufacturing system performance (utilization). The optimization sought, allocates product volumes to alternative process technologies at each stage in the manufacturing process.

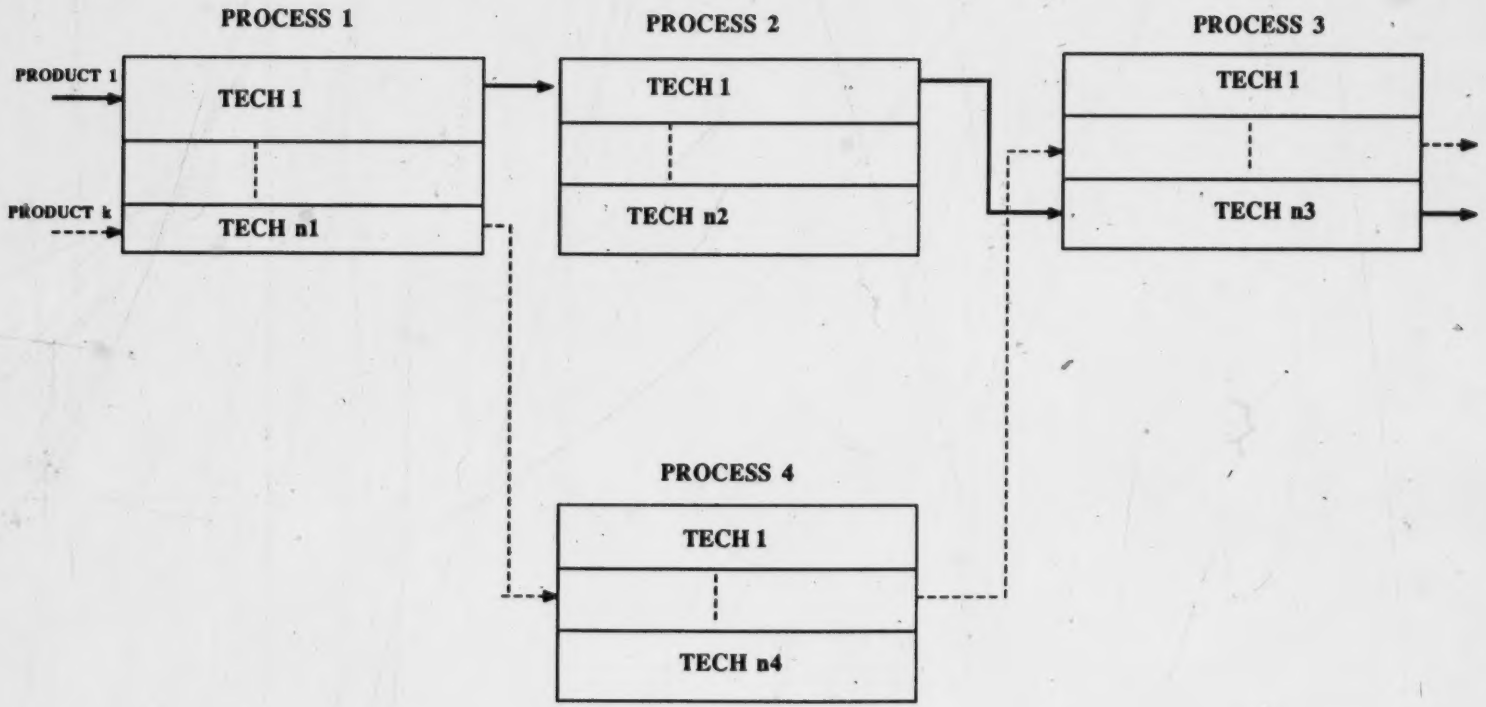


FIGURE 9.4. MATHEMATICAL MODEL STRUCTURE

Let p, t, and k represent indices for the manufacturing process (stage), technology alternative and product class, respectively. Let us define discrete input parameter s_{pt} and choice variable q_{ptk} as follows:

$s_{pt} = 1$ if technology t is available for process p

$= 0$ otherwise.

and

$q_{ptk} = 1$ if product k is allocated to technology t within process p

$= 0$ otherwise.

Let $V_p(q)$ be the minimum variable production cost for process p ($V_p(q) = \sum_{t,k}[V_{ptk} X_{ptk}]$) given the values for s_{pt} and q_{ptk} specified in vector q. The process production volume is decomposable for each p. The overall choice problem is

$$\min \sum_p \left(\sum_t F_{ptk} q_{ptk} + \sum_{t,k}[V_{ptk} X_{ptk}] \right)$$

s.t

$$\sum_p s_{pt} \leq TL_p \quad \text{.....(1)}$$

$$\sum_k q_{ptk} \leq PL_{pt} \quad \text{.....(2)}$$

$$\sum_k r_{ptk} X_{ptk} \leq CAP_{pt} \cdot s_{pt} \quad \text{.....(3)}$$

$$\sum_t X_{ptk} \geq R_{pk} \quad \text{.....(4)}$$

$$R_{pk} = \rho_{pk} \cdot X_k \quad \text{.....(5)}$$

$$\underline{X}_{ptk} \cdot q_{ptk} \leq X_{ptk} \leq X_{ptk} q_{ptk} \quad \text{.....(6)}$$

$$X_{ptk} \geq 0 \quad \text{.....(7)}$$

s_{pt} , q_{ptk} are (0,1) and fixed.

where:

(i) F is the fixed cost of technology t, process p.

(ii) TL and PL are the upper limits on the number of technologies per process and the number of products assigned to process p, and technology t respectively.

(iii) R_{pk} are the production requirements for product k at process stage p.

(iv) X_{ptk} is the production volume for process p, technology t, and product k.

(v) V_{ptk} is the variable production cost for ptk.

(vi) $\underline{X}_{ptk}$, X_{ptk} are the lower and upper bounds on production volume.

(vii) r_{ptk} is the capacity utilization rate for product k at pt.

(viii) ρ_{pk} is the routing indicator variable(ρ_{pk} =1 if the product k is processed at process p and 0 otherwise).

(ix) X_k are production requirements for product k.

(x) CAP_{pt} is the capacity for technology t process p.

Eqn.(1) and Eqn(2) are the upper limits on the number of technologies per process and the number of products assigned to process p technology t. Eqn(3) is the capacity constraint. Eqn(4) is the production requirement constraint, eqn(5) is the process production requirement constraint. Eqn(6) is the bounds for production volumes, and Eqn(7) is the non-negativity constraint.

The inputs requirements of the model are, plant capacities, product costs, production requirements, purchasing costs, and process details of

products (operation times and routing). The outputs are process selection(list of parts to be made in-house and those that are to be sub contracted out), production costs, and performance estimates.

To clarify the model, let us consider an example. For sake of simplicity only two products(A and B), four processes(P1, P2, P3 and P4), and two technologies(T1 - in-house and T2 - vendor) are considered. The production requirements for the two products (X_k) are [500, 1000]. The process production requirements(X_{ptk}) could be different from this requirement, depending on process losses and other factors.

The product routing information ρ_{pk} is shown below

	P1	P2	P3	P4
Prod. A	1	1	1	0
Prod. B	1	0	1	1

The time required(mins) to process each of the parts at the process stage is shown below(capacity utilization rate r_{ptk})

	P1	P2	P3	P4
Prod. A	3	4	2	0
Prod. B	2	0	1	6

The capacity for the time period under consideration is shown below (CAP_{pt})

	P1	P2	P3	P4
T1	2000	2000	2000	4000
T2	10000	10000	10000	10000

Outside capacity is given a very large number to assume enough capacity. The variable production cost($) is shown below

		P1	P2	P3	P4
Prod. A	T1	3	4	4	0
	T2	3	4.5	5	0
Prod. B	T1	6	0	2	3
	T2	5	0	2	4

Fixed costs for placing an order on the vendor is $20. The fixed costs then can be shown as below

	P1	P2	P3	P4
T1	15	25	20	15
T2	20	20	20	20

Considering process P1 alone, we can define(omitting subscript p)

$$V_1(q) = \text{Min} (V_{11} X_{11} + V_{12} X_{12} + V_{21} X_{21} + V_{22} X_{22})$$

which is $\text{Min} (3X_{11} + 6X_{12} + 3X_{21} + 5X_{22})$

S.T

$$3X_{11} + 2X_{12} \leq 2000$$

$$3X_{21} + 2X_{22} \leq 10000$$

$$X_{11} + X_{21} \geq 500$$

$$X_{12} + X_{22} \geq 1000$$

Solving for all X's, we have $X_{11} = 500$, $X_{12} = 0$, $X_{21} = 0$, and $X_{22} = 1000$ which means produce Product A in-house and farm out Product 2. We can solve for other processes similarly and find the production process selections. For process 3 we have $X_{11} = 500$, $X_{12} = 1000$, $X_{21} = 0$, and $X_{22} = 0$ which suggests that both Product 1 and Product 2 should be produced in-house. The total minimum cost can be obtained adding the fixed costs to the minimum value of the objective function solved, as above. The capacity slack can also be obtained from the solution and if needed a ranging analysis can be done on the variables

The selection of a model for processing is very important. The models should be carefully chosen to form a DSS in each of the functional areas and within each functional area. The models have to be reliable and should not have many restrictions.

10. CONCLUSION

The purpose of this two part study is to design the major modules of the capacity requirement planning and costing system for a microcomputer based Integrated Production and Inventory Control System and to discuss the design of a Decision Support System(DSS) for strategic planning.

The Capacity Requirements Planning(CRP) system developed has fulfilled the objectives set out for it to perform, viz.,

(i) Interface with the Material Requirements Planning(MRP) system.

(ii) Create and maintain shop database.

(iii) Develop realistic shop schedule.

(iv) Calculate manufacturing cost for parts produced.

(v) Prepare reports for management.

The main modules of the CRP have been developed using the BASIC programming language. The programs are menu-driven and are user-friendly.

The CRP system has been partially tested with an actual implementation at Argo Material Handling System Limited. The CRP system has been designed to operate along with a material requirements planning(MRP) system so that material planning and scheduling functions can be integrated to achieve the benefits of each of the systems. The result is an improvement in material control and shop planning activities.

The partial implementation of the system made a very important point, that any system will have to be modified and tailored to suit the needs of the individual user. The implementation of the system clearly created an awareness of the kind of problems that one should solve during implementation in an organization not familiar with a computerized system. In this regard two problems deserve mentioning. (i) running the system initially when the databases are not accurate, and (ii) generating the MRP matrix for calculating the net requirements of parts.

The MRP/CRP systems require that the databases are complete and accurate if the schedules developed are to be realistic. However collecting the stock status information and the shop processing time information usually takes a very long time, even upto one year. To override this rigid requirement, a special program has been developed which will override the MRP and develop shop route sheets(instead of schedules) to be circulated in the shop. This will enable the company to gather valuable shop processing time information, allow the shop personnel to get acquainted with the system, and provide enough time for the concerned personnel to develop the discipline and dedication that a computerized system needs to succeed.

This study was also aimed at designing the data bases forming part of a decision support system(DSS) for strategic planning. The database information that is required to form part of a DSS in the capacity planning area has been presented. The actual data record formats are not presented as they will depend entirely on the organizational needs. The

benefits of the long range planning(LRP) process has been emphasized and the steps involved in developing a strategic plan has been briefly discussed. It is hoped, small businesses that plan to install a computerized system like the MRP/CRP will gradually extend the system to cover the planning activities as well.

A conceptual model for analyzing a decision making process in an organization has been presented. A mathematical programming model for analyzing make/buy decisions has been suggested and it can form part of the DSS that can embellish the MRP/CRP system. The success of the computerized system depends entirely on the organizational culture. The databases must be maintained accurately and the system should not be over-ridden except in an emergency.

The program source code and file formats are available for modification in future installations.

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APPENDIX A

USER'S MANUAL FOR RUNNING THE CAPACITY REQUIREMENTS PLANNING SYSTEM

(The following pages describe the CRP software, their purpose, requirements and inputs for the new user of the CRP application software).

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I SYSTEM REQUIREMENTS AND PROGRAM LOADING INSTRUCTIONS

This is a **Capacity Requirements Planning(CRP)** system that runs on the IBM Personal Computer(PC) as part of the Production and Inventory Control System. The minimum hardware requirement is an IBM PC or compatible with dual disk drives of 360K each, 64K of RAM, and a printer for hard copy outputs and reports.

The CRP system is designed to operate along with a **Material Requirements Planning(MRP)** system. The CRP system will access the inventory master files, bill-of-materials(BOM) file and the MRP-matrix, created and maintained in the MRP. To acquaint yourself with these please refer to the operating instructions of the MRP system.

The amount of inventory data that can be stored on a double sided double density 360K diskette is approximately 1000 stock items. Larger inventory bases should use a hard disk for data storage.

To start using the system, you will need the CRP program disk and a formatted disk for data storage. Refer to the DOS manual on how to format a disk, if you do not know.

There are a total of thirty-two BASIC program files with extension .BAS on the diskette. In addition, there are thirteen data files(.DAT), one batch file(CRP.BAT) and one system file (CONFIG.SYS). A copy of IBM's

BASIC language interpreter Version 3.0 is also included on the diskette. If you are using a machine other than IBM's, please make sure to replace this version of BASIC with the one recommended for your machine before running the programs.

You will need a DOS system disk to boot the machine. Make sure that you have a CONFIG.SYS file on it, or else copy the one from the CRP diskette. Make sure that the CONFIG.SYS file has the command FILES=12. This is required as the CRP will access as many as eight Input/Output files simultaneously. More instructions can be found in the DOS manual. It is recommended that you make a working copy of the CRP diskette and keep the original in a safe place. Refer to the DOS manual on how to copy a disk.

After the computer has been turned on and the DOS prompt appears, insert the CRP diskette into drive A (the one on the left or at the top), and type CRP. You will then be prompted to enter the new date and time. It is important that the system has the correct date and time so as to correctly store and retrieve historical data.

After you have entered the date and time, the computer will load the program into the memory. The first message that you will see on the screen is shown in Figure A.1. You should enter D if you have a dual disk drive or H if you have a hard disk drive for data storage. The program will then prompt you to enter the letter of the diskette drive(if you had entered D) or the name of the hard disk directory(if you had entered H).

This information regarding the location of data storage is transferred to other menu driven programs that you might access. If your data files will be maintained in a fixed location, it is better to include it in the program itself rather than entering it every time you run the CRP. Any knowledgeable user can hard code this in the program CRPINTRO.BAS .

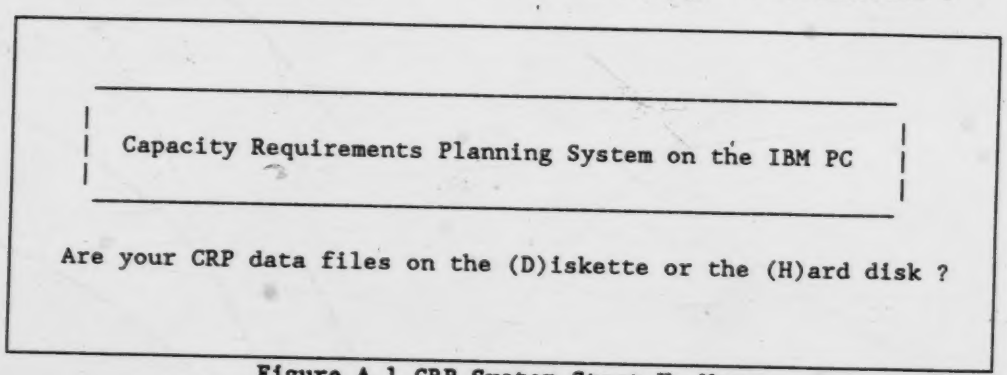

Figure A.1 CRP System Start Up Menu

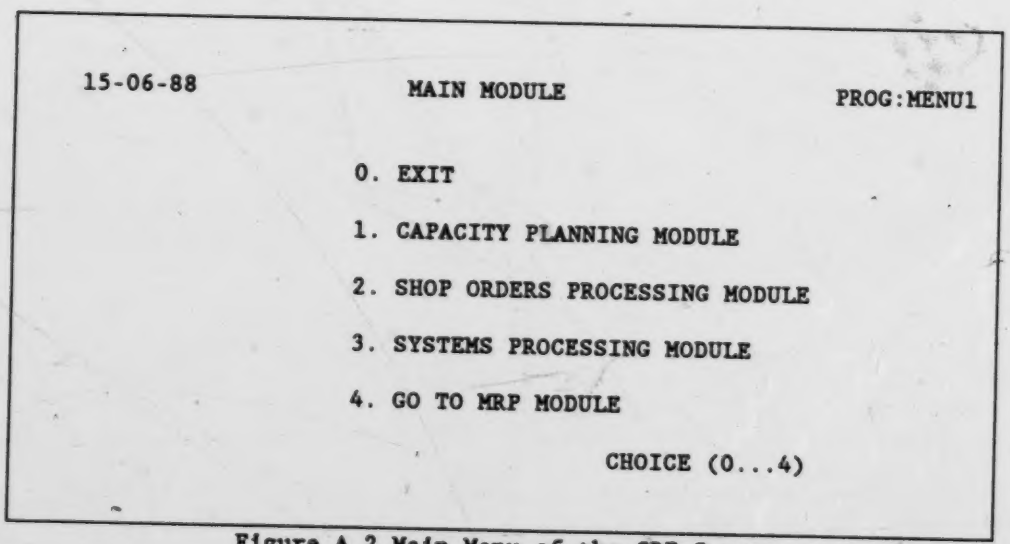

Figure A.2 Main Menu of the CRP System

Programs in the CRP application software are menu-driven and user-friendly. The main menu is shown in Figure A.2. It consists of three processing modules, each having their own sub-menus and sub-programs for processing the corresponding data.

If you are using the system for the first time or if you are entering data for a different company, you should go to the System Processing Module and run program #5, to create the initial data files on your diskette before running other programs. The following pages explain the various programs.

II CAPACITY PLANNING MODULE

```
15-06-88        CAPACITY PLANNING MODULE          PROG:MENU2

                0. EXIT
                1. ITEM/ASSEMBLY INQUIRY
                2. INPUT WORK CENTER/ OPERATION SEQUENCE DATA
                3. DELETE/REPLACE/ADD SEQUENCE
                4. PRINT WORK CENTER/ OPERATION SEQUENCE DATA
                5. BATCH SIZE DETERMINATION
                6. CAPACITY PLANNING REPORT
                7. MATERIAL REQUISITION LIST

                                        CHOICE (0..7)
```

Figure A.3 Capacity Planning Menu

1. **Item/assembly inquiry** - display all the stock details on the screen plus any outstanding orders relating to the particular stock.

2. **Input work center/operation sequence data** - create/amend details regarding a work center, or create/copy operation sequence for a part.

3. **Delete/replace/add sequence** - amend existing details of the operation sequence of a part.

4. **Print work center/ operation sequence data** - display details of a work center(s), or details of the operation sequence of a part(s) on the screen or print it out on a printer.

5. **Batch size determination** - create an economic batch quantity (EOQ or EBQ) for a part(if known) or calculate an EOQ based on historic data.

6. **Capacity planning report** - read information from the MRP-matrix and compute capacity requirements. Cumulative work load for each work center is maintained and compared to available capacity and a report is generated.

7. **Material requisition list** - prepare list of raw material/parts to be issued to the production shop to complete the current production schedule.

1. ITEM/ASSEMBLY INQUIRY

Enter the part number of the item/ assembly you wish to look at and all of its detail will be displayed on the screen.

```
15-06-88                ITEM/ASSEMBLY INQUIRY          PROG:ITEMINQY


1. ASSY NUMBER:[ALW15400] 2. DESCRIPTION :[LIP WELDMENT 6W 25000]
3. QTY. ON HAND : 0       4. PROD. ORDERS : NO OUTSTANDING ORDERS
5. LEAD TIME : 1          6. LAST INVENTORY TAKEN ON : 12-05-88
7. UNIT COST : $ 550.00   8. LAST PRODUCTION RUN DATE: 14-06-88
9. USED ON :
   FDH15410     DOCK LEV. 68 DH. 25000 MECH. LIP
   FDL14600     DOCK LEVELLER 6x6 20000#
   FDL15400     DOCK LEVELLER 6x8 25000#
   FDL15800     DOCK LEVELLER 6x8 35000#
   FDL17000     DOCK LEVELLER 6x10 25000#

   Hit <ENTER> after reading details!
```

Figure A.4 Item Inquiry Menu

Note:(i) If the part is a purchase item, then field #4 will be Purchase Orders and field #8 will be Last Purchase Date.

(ii) If the part is a finished product or if the part has no BOM relationships, then field #9 USED ON: will display,

Above part is a finished product. No used on information!.

Type in a * in the part number field to exit the program.

2. INPUT WORK CENTER/ OPERATION SEQUENCE DATA

This program is used to create a new work center, amend work center details or create/copy operation sequence for a part. The menu is shown in Figure A.5

```
15-06-88        WORK CENTER MODULE                PROG:MENU3

                0. EXIT
                1. INPUT WORK CENTER DATA OR QUERY
                2. INPUT OPERATIONS SEQUENCE

                                  CHOICE (0..2)
```

Figure A.5 Work Center/Operations Sequence Menu

Input work center data or query - there are 11 fields that the user has to enter to create a new work center(Figure A.6).

1. **WORK CENTER #** - enter any character string of length 3, the program will check the work center database to determine if it is a new work center. If it is, the program will prompt,

NEW WORK CENTER (YES/ NO)

The user at this point should check to see if the work center number just entered is correct. Enter Y if it is a new and correct number, otherwise enter N to clear the entry and enter another number. If the work center number entered already exist, the program will display the details (Figure A.7) and prompt,

```
15-06-88          WORK CENTER DATA          PROG:WORKCENT

 1. WORK CENTER # :[A01] 2. WORK CENTER NAME :[                ]
 3. LOCATION      :      4. DESCRIPTION      :[                ]
 5. NORMAL CAPACITY:     6. MAX. CAPACITY:
                         7. EFFY. FACTOR:
 8. SET UP RATE :        9. MACHINE RATE :
10. LABOR RATE  :       11. OVERHEAD RATE:
     NEW WORK CENTER    (Yes/No)
```

Figure A.6 Work Center Maintenance Menu

A(mend) U(pdate) I(gnore)

Make appropriate selection.

2. **W.C NAME** - enter the name of the work center, maximum permissible length is 25 characters. Use description field if greater than 25 characters.

3. **LOCATION** - enter any character string of length 3. This field is used for material handling purposes.

4. **DESCRIPTION** - enter any character string upto length 25. This field is designed to contain information about the work center other than what has been entered in W.C. NAME.

5. **NORMAL CAPACITY** - enter the amount of time in minutes available in minutes each working day. For example, if your company operates only a single shift of 8 hours duration, and if the effective production time

available is 7 hours, then the normal capacity is 420 minutes.

6. **MAX. CAPACITY** - enter the amount of time in minutes that could be made available each working day. If your company policy will permit you to work overtime or operate an extra shift if needed, the additional time available should be added to the normal capacity. For example, if an extra 3 hours of production time could be made available then the maximum capacity is 600 minutes(7+3 hours). The maximum capacity should at least be equal to normal capacity.

7. **EFFY. FACTOR** - enter the expected throughput of the work center. For example, if the expected rejection rate is 5%,
then the throughput is 95%. Enter 95.0 in this field.

8. **SETUP RATE** - enter the $/Hr. rate for setting up the work center.

9. **MACHINE RATE** - enter the $/Hr. rate for running the work center.

10. **LABOR RATE** - enter the $/Hr. rate paid to the operator of the work center.

11. **OVERHEAD RATE** - enter the $/Hr. rate that should be charged as overhead for operating the work center.

After entering the last field(or if the work center number existed in the file) you will be prompted(Figure A.7),

A(mend) U(pdate) I(gnore)

If you are satisfied with your inputs choose U and the details will be updated and the following message will be displayed.

Work center details updated. Hit <ENTER> to continue.

Press the **<ENTER>** key to enter a new number.

If for some reason you feel that the information in some field needs to be changed then choose **A** and enter the field number you want to change.

```
15-06-88          WORK CENTER DATA              PROG:WORKCENT

 1. WORK CENTER # :[A01] 2. WORK CENTER NAME :[LATHE          ]
 3. LOCATION      :A11   4. DESCRIPTION      :[TURRET LATHE   ]
 5. NORMAL CAPACITY:500  6. MAX. CAPACITY: 900

                         7. EFFY. FACTOR:   95.0

 8. SET UP RATE : 6.00   9. MACHINE RATE :  14.00

10. LABOR RATE  :12.00  11. OVERHEAD RATE:   4.00

        A(mend)   U(pdate)   I(gnore)
```

Figure A.7 Work Center Maintenance Display

You can choose **A** as many times as you wish. After making all the necessary changes choose U to update or I to ignore the inputs.

Note: You will not be permitted to change the work center number once it has been entered in the file.

If there are a lot of work centers in the file, then it will be useful to view the existing work centers before choosing a new number. Enter a ? in the work center number field and the existing work centers will be displayed, as shown in Figure A.8. Follow the instruction. To quit halfway hit the <ESC> key.

Type in a * in the work center number field to exit the program.

Input operation sequence data - enter the part number you want to input operation sequence for. If the part number exists in the part master file and if there is no existing operation sequence information for the part

WC#	DESCRIPTION	LOCN	NOR. CAP.	MAX CAP.	EFFY %	SETUP RATE	M/C RATE	LABOR RATE	O.H. RATE
A01	MILLING M/C	111	450.0	800.0	80.0	4.0	3.0	12.0	5.0
A02	LATHE	A11	500.0	900.0	95.0	6.0	14.0	12.0	4.0
A04	PUNCH PRESS	ALT	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HIT ANY KEY TO CONTINUE

Figure A.8 Work Center Listing

then you will be allowed to proceed. The following message will be displayed(Figure A.9).

15-06-88 OPERATIONS SEQUENCE PROG:OPSEQ

PART NUMBER:[CFB22000] DESCRIPTION :[2x3 FLAT BAR x 1 THICK]

RTINDEX file has been updated. Hit <ENTER> to continue.

Figure A.9 Operation Sequence Menu

RTINDEX file has been updated. Hit <ENTER> to continue.

After you hit **<ENTER>** you will be prompted,

Do you want to copy operation (Yes/No)

If you enter **Y** you will be prompted,

Please enter part number to copy operations

You can enter the part number. If the part number exists then the following message will be displayed.

Operation details copied. Hit <ENTER> to continue.

However if no operation details exist for the specified part the following message will be displayed.

Operations for specified part do not exist.

Do you want to try again (Yes/No)

Enter Y if you want to try again or else enter N to input from keyboard(Figure A.10)

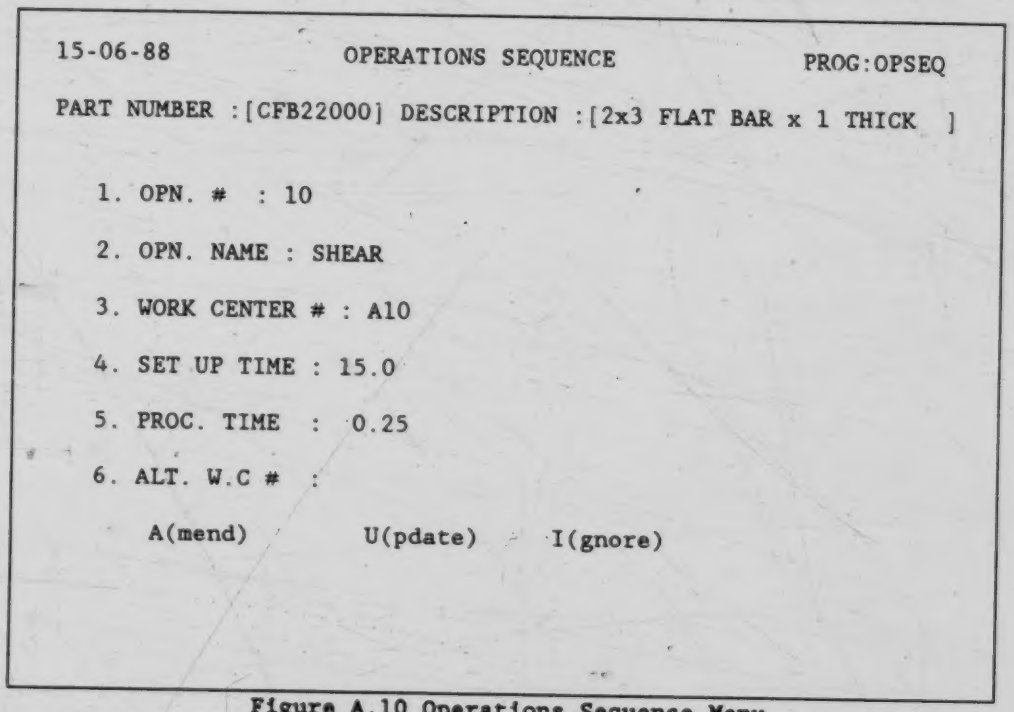

Figure A.10 Operations Sequence Menu

There are 6 field that have to be entered for each operation.

1. OPN. # - enter a positive integer. (Note: (i) The operation # denotes the sequence of operation. (ii) Two operations cannot have the same operation #. (iii) The operations need not be entered in sequence. The program will sort out the sequence.(iv) Operation # should be less than 9990. (v) Adequately space operation numbers to permit future changes.

For example, use 10, 20 etc., instead of 1,2..

2. OPN. NAME - enter the name of the operation(maximum 30 characters).

3. W.C. # - enter the number of the work center where the operation will be performed.(Note: The work center number must exist in the work center file otherwise you will not be allowed to continue).

4. SET UP TIME - enter the time in minutes needed to set up the work center to perform the operation.

5. PROC. TIME - enter the time in minutes needed to complete the operation on one piece.

6. ALT. W.C.# - optional entry. If the specified operation can be done at more than one work center, than you can enter that work center number. The work center must exist.

After entering the last field you will be prompted,

A(mend) U(pdate) I(gnore)

Follow the instructions to amend a field.

To end the sequence for the part enter 0 in the Opn. # field. You will be prompted to confirm,

Do you want to end operation (Yes/No)

Enter Y to end the operation for the part and you can start entering a new part number if you want.

Enter a * in the part number field to exit the program.

3. DELETE/REPLACE/ADD SEQUENCE

This program is used to edit the operation sequence information for an existing part. Enter the part number you want to edit and choose from,

Delete/Replace/Add

15-06-88 OPERATIONS SEQUENCE PROG:EDITOP

PART NUMBER:[CCS22000] DESCRIPTION:[3/4 DIA BAR x3-3/4 LG CRS]

OPN. #	DESCRIPTION	WC#	STIME	PTIME	ALT WC#
10	SHEAR	A01	0.0	0.0	
20	PUNCH HOLE	A02	0.0	0.0	
30	DEBURR	A03	0.0	0.0	A15

Make a selection from DELETE/REPLACE/ADD

Figure A.11 Operations Sequence Editing Menu

Delete option - enter D to choose the delete option. You will be prompted,

Do you want to delete entire operations. (Yes/No)

Enter Y if you want to delete all the operations of the part. If you enter N you will be prompted,

Please enter # of operation to be deleted.

Enter the operation number you want to delete and the following message will be displayed.

Specified operation deleted. Any more deletions (Yes/No)

Enter Y if you want to delete another operation or enter N to end deletions.

Replace option - enter **R** to choose the replace option. You will be prompted,

Please enter operation # to be replaced.

Enter the operation number for which you want to change details and follow the instructions.

Add option - enter **A** to add/insert operations. The following message will be displayed.

System ready to accept addition(s). Hit <ENTER> to continue.

This is similar to entering operation sequence. To end sequence enter 0 for Opn. #.

Enter a * in the part number field to exit the program.

4. PRINT WORK CENTER/ OPERATION SEQUENCE INFORMATION

Choose the appropriate number from the print sub-menu shown in Figure A.12

```
15-06-88    WORK CENTER/OPERATIONS SEQUENCE DETAILS    PROG:PRINT

                    0. EXIT

                    1. WORK CENTER DETAILS

                    2. OPERATIONS SEQUENCE DETAILS
```

Figure A.12 Work Center/Operation Sequence Print Menu

Enter the range of numbers(starting and ending numbers for either work center or part as the case may be). The program will prompt you to choose the output device(Figure A.13 and Figure A.14).

```
15-06-88          WORK CENTER DETAILS                PROG:PRINT

STARTING NUMBER :[A01]          ENDING NUMBER :[B99]

                                SCREEN/PRINTER   (S/P)
```

Figure A.13 Work Center Print Menu

```
15-06-88      OPERATIONS SEQUENCE DETAILS          PROG:PRINT

 STARTING NUMBER :[00000000]      ENDING NUMBER :[ZZZZZZZZ]

                                    SCREEN/PRINTER   (S/P)
```

Figure A.14 Operations Sequence Print Menu

WC#	DESCRIPTION	LOCN	NOR. CAP.	MAX CAP.	EFFY %	SETUP RATE	M/C RATE	LABOR RATE	O.H. RATE
A01	MILLING M/C	111	450.0	800.0	80.0	4.0	3.0	12.0	5.0
A02	LATHE	A11	500.0	900.0	95.0	6.0	14.0	12.0	4.0
A04	PUNCH PRESS	ALT	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HIT ANY KEY TO CONTINUE

Figure A.15 Work Center Listing on Screen

Currently printing operation for part # CSS22000

OPN.#	DESCRIPTION	WC#	STIME	PTIME	ALT WC#
10	SHEAR	A01	0.0	0.0	
20	PUNCH HOLE	A02	0.0	0.0	
30	DEBURR	A03	0.0	0.0	A15

HIT ANY KEY TO CONTINUE

Figure A.16 Operations Sequence Listing on Screen

Enter S if you want to view on the screen(Figure A.15 and Figure A.16), or else enter P to produce a hard copy on the printer(in addition, for operations sequence, you could specify if you need a form feed after every part).

To view the files enter a ? in the starting number field.

Enter a * in the starting number field to exit the program.

5. BATCH SIZE DETERMINATION

```
15-06-88          BATCH SIZE DETERMINATION          PROG:BATCHQTY

PART NUMBER :[ALW15450]     DESCRIPTION :[LIP WELDMENT 6W 25000#]

    LAST 12 MONTH DEMAND =  0 Units

    EXISTING BATCH SIZE  =  5 Units

          Do you want to change batch size.  (Y/N)
```

Figure A.17 Batch Sizing Menu

This program is used for calculating the economic order quantity(EOQ), the max. inventory level, total average cost of the EOQ policy, and the re-order level.

Enter the part number for which you want to calculate or change the batch size. The existing batch size and the past year's demand will be displayed. Enter Y to change the batch size or N to ignore the part. If you entered Y you have the option to enter a batch size or calculate a batch size. Follow the instructions.

EOQ calculation option - there are two models available(infinite production model and finite production model). For the infinite production model you will have to enter the following (Figure A.18).

1. Expected demand rate in units per year - enter the expected yearly demand for the part.
2. Ordering cost - enter the ordering or set up cost for the part.
3. Inventory Carrying Cost - enter the inventory carrying cost as a fraction of the cost of the part.
4. Unit cost - this information will be read from the master file.

```
15-06-88        BATCH SIZE DETERMINATION          PROG:BATCHQTY

   1. Expected demand rate in units per year  -    100
   2. Fixed ordering/setup cost               - $ 50.00
   3. Inventory carrying cost rate (0<ICC<1)  -    0.15
   4. Unit variable cost                      - $550.00
   5. Procurement lead time(weeks)            -    2

   A(mend)        I(gnore)        C(alculate  EOQ)
```

Figure A.18 Batch Size Determination Inputs

5. **Lead time** - this information will also be read from the master file. You will be prompted,

A(mend) I(gnore) C(alculate EOQ)

The output is shown in Figure A.19.

Note: The finite production model is similar, except that the production rate has to be entered.

```
15-06-88        BATCH SIZE DETERMINATION          PROG:BATCHQTY

   1. Economic batch size (EOQ)                 -   11
   2. Maximum inventory                         -   11
   3. Cost of procuring/producing 100 units-  $55000.00
   4. Average annual ordering/setup cost        - $ 454.15
   5. Average annual holding cost               - $ 454.15
   6. Total average annual cost                 - $55908.30
   7. Procurement/production cycle              -  40 Days
   8. Lead time demand                          -  4  Units
   9. Reorder point                             -  4  Units
      Existing batch size                       -  5  Units
      Hit <ENTER> to continue after viewing results
```

Figure A.19 Batch Size Determination Output Format

6. CAPACITY PLANNING REPORT

15-06-88 CAPACITY PLANNING REPORT PROG:WORKLOAD

The output of the production plan is the Master Production Schedule(MPS) which in turn leads to MRP. The MRP computes the net requirements for each and every part based on the customer orders and forecasts for an eight week period.

This program will read the MRP matrix information and compute the production time requirement and check for capacity overruns. This program will also prepare a list of parts that need to be purchased.

The production quantity that will be considered is

MAX(net requirement, EOQ).

Make sure that the MRP matrix has been regenerated before running this program. Also make sure that the last shop schedule has been updated for all the work completed.

DO YOU WISH TO PROCEED. (Yes/No)

Figure A.20 Capacity Planning Report Menu

Enter Y to proceed or N to exit. If you entered Y you will be prompted,

Enter number of weeks to be included in plan(<=8)

Note: It is not advisable to choose more than two weeks if the MRP is regenerated on a weekly basis.

After all the MRP matrix information has been read the following message will be displayed.

Production and Purchase requirements have been written to files. Make a selection from,

0. EXIT
1. CAPACITY REQUIREMENT REPORT
2. PURCHASE REQUIREMENT REPORT
CHOICE (0..2)

15-06-88 CAPACITY REPORT PROG:WORKLOAD

PLAN PERIOD: 15-06-88 to 20-06-88

WC#	CAPACITY(HRS)	EST. LOAD(HRS)	% OF CAPACITY	REMARKS
A01	200	160	80.0	
A10	200	180	90.0	
B20	160	200	125.0	OVERLOAD
B99	100	100	100.0	CRITICAL LOAD

Figure A.21 Capacity Report Display

Choose 0 to exit. The capacity report or purchase report could be directed to the screen or printer. Sample screen outputs are shown in Figure A.21 and Figure A.22.

15-06-88 PURCHASE REPORT PROG:WORKLOAD

PLAN PERIOD 15-06-88 to 20-06-88

PART #	DESCRIPTION	QTY. REQD.	SUGGESTED EOQ
P1000010	3/4 DIA PIN	240	400
CBS00100	BRASS BUSHING	72	80

Figure A.22 Purchase Report Screen

7. MATERIAL REQUISITION LIST

15-06-88 MATERIAL REQUISITION LIST PROG:MATLREQ

PLAN PERIOD 15-06-88 to 20-06-88

PART #	DESCRIPTION	QTY. REQD.	QTY.ISSUED
UFB22000	2x3 FLAT BAR 120 LG	12	
URS00100	2x2 RECT. 100 LG	10	

Authorized by:

Figure A.23 Material Requisition List

This program is used to generate the material requisition needed by the production shop to draw materials from the stores to fulfill the current production schedule. This is useful for transporting material and for material control.

Enter the number of days that you want the list to cover and the output device to which the report is to be routed(screen/printer).
Once material has been issued to the shop, further material will not be allowed to be drawn on the same shop schedule. The screen output is shown in Figure A.23.

II SHOP ORDER PROCESSING MODULE

```
15-06-88    SHOP ORDER PROCESSING MODULE          PROG:SHOPMENU

                0. EXIT
                1. DETAILED WORK CENTER SCHEDULING
                2. SHOP SCHEDULE REPORT
                3. WORK UPDATING AND RESCHEDULING
                4. SHOP STATUS ENQUIRY
                5. OPERATION TIME HISTORY
                6. SHOP WORK ORDER RELEASES

                                        CHOICE (0..6)
```

Figure A.24 Shop Order Processing Menu

1. **Detailed work center scheduling** - prepare the work center schedule based on a scheduling method chosen by the user.

2. **Shop schedule report** - print a prepared schedule on the screen or on the printer. Option exists for amending quantity and/or priority.

3. **Work updating and rescheduling** - this program updates the completed work and maintains the schedule file for rescheduling.

4. **Shop status enquiry** - display current status of the shop or a particular work center on the screen.

5. **Operation time history** - maintain a historical record of actual processing times for future scheduling purposes.

6. **Shop work order releases** - prepare shop schedule over riding MRP. Requires user inputs on part number and quantity required, and a work order will be produced without considering capacities. This is only to be used initially when the system is being setup and until the system data bases are updated.

1. DETAILED WORK CENTER SCHEDULING

```
15-06-88        DETAILED WORK CENTER SCHEDULING        PROG:SHOPLOAD

This program must be run only after the CAPACITY PLANNING REPORT
program has been run, as it requires the input from it. Please
ensure that it has been run!

                    0. EXIT
                    1. EDIT SHOP SCHEDULE LIST
                    2. EARLY DUE DATE SCHEDULE
                    3. SHORTEST PROCESSING TIME SCHEDULE
                    4. SHORTEST REMAINING JOB SLACK SCHEDULE
                    5. FIRST COME FIRST SERVE SCHEDULE

                                              CHOICE (0..5)
```

Figure A.25 Detailed scheduling Menu

Enter the number of your choice.

1. **Edit schedule list** - Choose this option if you want to change the quantity and/or priority of parts before scheduling. The shop load prepared from the CAPACITY PLANNING REPORT will be displayed one screenful at a time and you can scan through and make the necessary amendments(Figure A.26).

Enter **A** and the line number to make changes to the quantity or the priority, **N** to view next screen or **E** to end edits and quit.

Schedule choices(2..5) - Choose a scheduling method that you want to use for preparing the shop schedule. The user will be prompted,

Have all changes in Qty./Priority been entered. (Y/N)

Enter **N** to exit to make changes. Enter **Y** if there are no changes to be made and a schedule will be prepared according to the rule chosen.

```
15-06-88              SHOP SCHEDULE EDITING    PROG:SHOPLOAD

   PART #          DESCRIPTION                QTY.     PRIORITY

1) CFB22000     2x3 FLAT BAR x1 THICK         85          N
2) CRS22000     2x2 RECT. BAR x 4 LG.         100         U
.                                .

  Make a selection from   A(mend)      N(ext)   E(nd)

PRIORITY CODES N-normal U-urgent R-rush B-backlog D-delay H-hold
```

Figure A.26 Edit Shop Schedule Menu

After the schedule has been generated the following message will be displayed,

Shop schedule has been generated !

Run Shop schedule report to view schedule.

Hit <ENTER> to exit.

2. SHOP SCHEDULE REPORT

```
15-06-88              SHOP SCHEDULE REPORT              PROG:SHOPREPT

 STARTING W.C # [A01]        ENDING W.C # [A10]

                                                  PRINTER/SCREEN (P/S)

 JOB ORDER # :AR011506                  WORK CENTER : A01  SHEAR

  PART #     DESCRIPTION      OPN     NAME              QTY.    TIME

1) CFB22000  2x3 FLAT BAR      10     SHEAR              45
2) CRS22000  2x2 RECT. BAR     35     SHEAR              75

 Hit <ENTER> to continue after viewing !
```

Figure A.27 Shop Schedule Report Menu

This program must be run after the detailed work center scheduling has been done. The user must input the starting and ending work center numbers for which the schedule is to be viewed/printed. If only one work center is needed, use the same number for starting and ending numbers. Enter the output device for the schedule, P for printer and S for screen.

3. WORK UPDATING AND RESCHEDULING

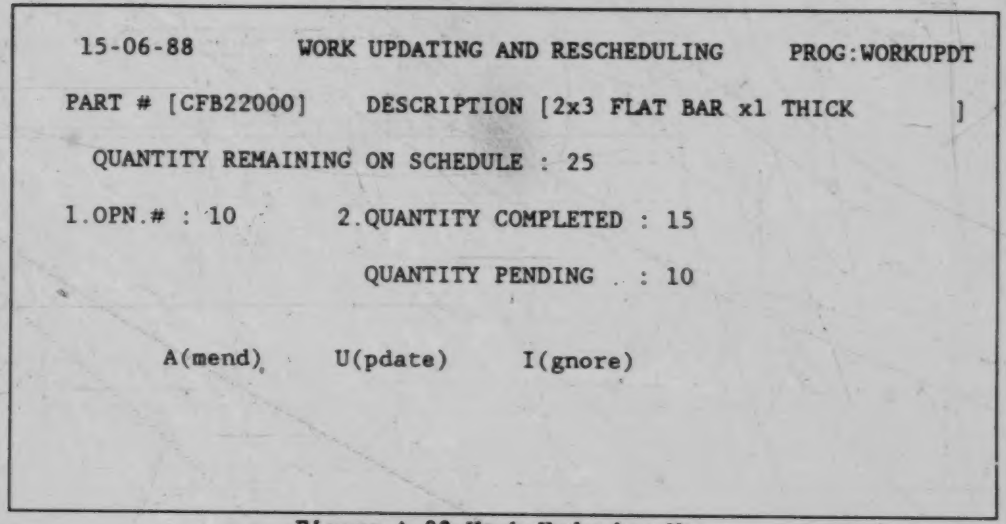
15-06-88 WORK UPDATING AND RESCHEDULING PROG:WORKUPDT
PART # [CFB22000] DESCRIPTION [2x3 FLAT BAR x1 THICK]
QUANTITY REMAINING ON SCHEDULE : 25
1.OPN.# : 10 2.QUANTITY COMPLETED : 15
QUANTITY PENDING : 10
A(mend) U(pdate) I(gnore)

Figure A.28 Work Updating Menu

This program is used to update completed work of the schedule prepared so that the necessary control codes can be written in the files. The user will be prompted for the part number, the opn.# and the quantity produced. A check will be made to see if the quantity pending is negative so that any input errors can be detected.

Enter **A** to amend quantity, **I** to ignore details on the screen and **U** to update information.

Enter a * in the part number field to end entering updates and the following message will be displayed,

E(xit)/R(eschedule)

Enter **E** to exit the program or **R** to reschedule the remaining work.

4. SHOP STATUS ENQUIRY

```
15-06-88        SHOP STATUS ENQUIRY              PROG:SHOPSTAT

  STARTING W.C # [A01]              ENDING W.C # [A10]

W.C#            SCHEDULED HRS.          COMPLETED HRS.

A01                   150                     85
A03                    75                     75
 .                      .                      .
 .                      .                      .
      Hit <ENTER> after viewing !
```

Figure A.29 Shop Status Menu

```
15-06-88              SHOP STATUS ENQUIRY              PROG:SHOPSTAT
  STARTING W.C # [A01]        ENDING W.C # [A01]
  JOB ORDER # :AR011506                 WORK CENTER : A01  SHEAR
  PART #    DESCRIPTION     OPN    NAME     SCH.QTY.    QTY.PROD
1) CFB22000 2x3 FLAT BAR     10     SHEAR    75          50
2) CRS22000 2x2 RECT. BAR    35     SHEAR    75          75
    .                         .
    .                         .
    .                         .
  Hit <ENTER> to continue after viewing !
```

Figure A.30 Shop Status Menu

This program is used to display the status of work in the shop. Enter the starting and ending work centers and the scheduled hours and completed hours will be displayed on the screen. If you enter the same number for the starting and ending numbers then the details of the parts

completed will be displayed(Figure A.30).

Enter a * in the starting work center number to exit the program.

5. OPERATION TIME HISTORY

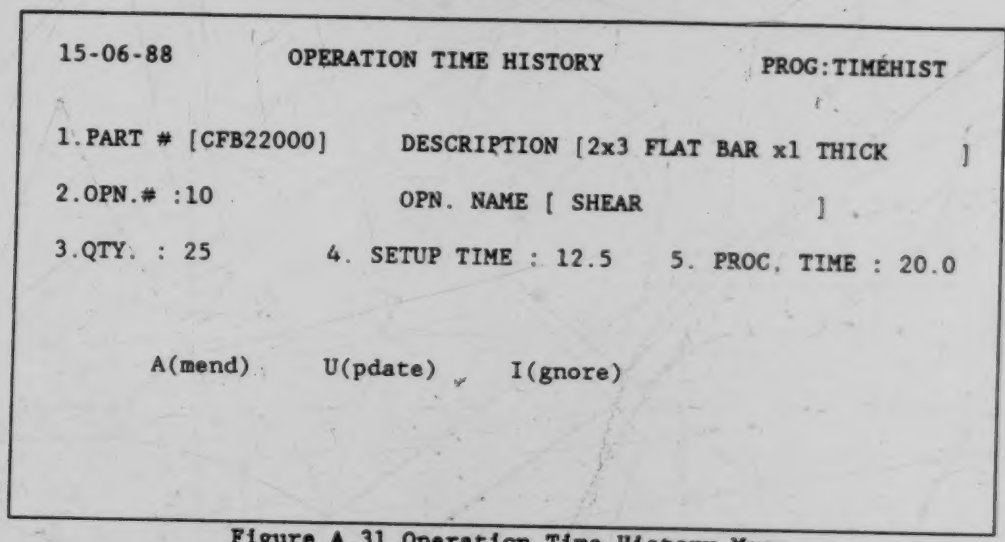
15-06-88 OPERATION TIME HISTORY PROG:TIMEHIST
1.PART # [CFB22000] DESCRIPTION [2x3 FLAT BAR x1 THICK]
2.OPN.# :10 OPN. NAME [SHEAR]
3.QTY. : 25 4. SETUP TIME : 12.5 5. PROC. TIME : 20.0
A(mend) U(pdate) I(gnore)

Figure A.31 Operation Time History Menu

This program is designed to collect operation time spent in producing parts. This information will be stored for future operation time estimates to be used for scheduling purposes. This program needs to be used only if there are no reliable time estimates available for production standards.

Enter the part number, operation number, the quantity produced and the time taken to produce the quantity in minutes.

Choose U to update entries, I to ignore and A to emend the entries.

Enter a * in the part number field to exit the program.

6. SHOP WORK ORDER RELEASES

```
15-06-88        SHOP WORK ORDER RELEASES          PROG:SHOPWORK

1.PART # [CFB22000]      DESCRIPTION [2x3 FLAT BAR x1 THICK    ]
2.QTY.  :10

                                  Please wait....Checking BOM..!
```

Figure A.32 Shop Work Order Release Menu

This program is designed for initial use when the system is first setup and the stock master files and time estimates are not very well established. When the inventory file information is incomplete it will be a waste of time to run the MRP and CRP scheduling programs to prepare a schedule because the MRP will then contain almost each and every part in the BOM of the finished product. Instead it will be faster to override the MRP and prepare a work list based on finished product requirements directly. This program does essentially that.

Enter the part number of the finished product that you want to produce and the quantity that you want. The BOM will be read and the list of parts to be produced will be sorted out based on operation and work centers.

Enter a * in the part number field to exit the program.

Note: The user will have to input each finished product separately and do a manual update for follow ups.

III SYSTEMS PROCESSING MODULE

```
15-06-88        SYSTEMS PROCESSING MODULE        PROG:SYSMENUS

                0. EXIT
                1. COSTING PROGRAMS
                2. MONTH-END PROCESSING PROGRAM
                3. MANAGEMENT REPORT GENERATION
                4. RANDOM INVENTORY COUNT GENERATION
                5. INITIAL SYSTEM DATA FILE SETUP
                6. REORGANIZATION OF DATA FILES
                7. CHAIN TO OTHER PROGRAM

                                        CHOICE (0..7)
```

Figure A.33 System Processing Menu

1. **Costing programs** - display cost information for a particular stock item, compute the manufactured cost of a product and comparison with historical costs.

2. **Month-end processing** - delete unwanted records from the shop schedule file of the current month and rolls the production history file forward by one month to make room for next month's entries.

3. **Management report generation** - prepares and displays management information regarding performance, exceptions, and shop utilization on the screen or on the printer.

4. **Random inventory count generation** - prepares a random list of parts based on user input for physical verification.

5. **Initial system data file setup** - use this program only once when the system is setup initially or for a new company.

6. **Reorganization of data files** - reorganizes the data files by deleting

unwanted records and logically arranging record in a sequential manner for faster access.

7. **Chain to other program** - provides a means to any other user written program which might access/manipulate the CRP system data files.

1. COSTING PROGRAMS

```
15-06-88        COSTING PROGRAMS                    PROG:COSTMENU

                0. EXIT
                1. COST INQUIRY
                2. SHOP ORDER COSTING
                3. HISTORICAL COSTS AND FORECASTS

                                                    CHOICE (0..3)
```

Figure A.34 Costing Program Selection Menu

Enter the number of your choice for the program that you want to access. 1.Cost inquiry - enter the part number of the part for which you want the cost information and it will be displayed on the screen(Figure A.35).

```
15-06-88            COST INQUIRY                    PROG:COSTINQY

 PART # [CFB22000]      DESCRIPTION [2x3 FLAT BAR x1 THICK .   ]

 DIRECT MATERIALS : $ 5.45

 DIRECT LABOR     : $ 7.37

 DIRECT OVERHEADS : $ 2.18

    TOTAL COST    : $15.00

    Hit <ENTER> after viewing details !
```

Figure A.35 Cost Inquiry Menu

Hit <ENTER> to clear the screen and key in another part.

To get the information for all the parts in the file enter a ? in the part number field and the cost details will be displayed, one screenful at a time(Figure A.36).

```
15-06-88              COST INQUIRY                    PROG:COSTINQY

    PART #     DESCRIPTION        DMATL    DLABR     DOVHD     TOTAL

1) CFB22000   2x3 FLAT BAR         10.00    12.12      3.00     25.12
2) CRS22000   2x2 RECT. BAR         5.60     7.40      2.00     15.00
      .                              .
      .                              .

   Hit <ENTER> to continue after viewing !
```

Figure A.36 Cost Inquiry Menu

Hit <ESC> to quit halfway.

Enter a * in the part number field to exit the program.

2.Shop order costing - this program will prompt the user for the job order number and will display the shop hours spent on that order and prompt for user inputs regarding administrative and selling costs. The order will then be costed.

3.Historical cost and forecast - enter the part number and the past 12 months' cost information will be displayed. A moving average forecast can be obtained(Figure A.37).

Enter a * in the part number field to exit the program.

```
15-06-88          COST INQUIRY                    PROG:HISTCOST

 PART # [CFB22000]      DESCRIPTION [2x3 FLAT BAR x1 THICK     ]

CURRENT  TOTAL COST     : $15.00

HISTORICAL COST INFORMATION :(BLANK MEANS NO INFORMATION)

 MAY 88 : $          APR 88 : $14.50     MAR 88 : $14.50

 FEB 87 : $          JAN 87 : $          DEC 87 : $

 NOV 87 : $          OCT 87 : $          SEP 87 : $

 AUG 87 : $          JUL 87 : $          JUN 87 : $

    Do You Want a Moving Average on Cost. Y/N

    Enter no of Months in Moving Average(≤ 12)
```

Figure A.37 Historical Cost Menu

2. MONTH-END PROCESSING

```
15-06-88          MONTH-END PROCESSING          PROG:MNTHEND

This month-end processing program should be executed only once a
month after all stock transactions for the current month have
been entered and reports printed.

The main functions of the month-end processing program are:

 (i) Remove completed work from the shop schedule file and update
     production history file.
(ii) Flag uncompleted work and change priority for scheduling.
(iii) Roll production history file forward by a month.
(iv) Maintain the work center performance and utilization in
     history files.

 IMPORTANT: All current month's transactions must be entered
            before running this program.

  HAVE ALL TRANSACTIONS FOR THE MONTH ENTERED   Y/N
```

Figure A.38 Month-end Processing Menu

The main functions of this program are to delete unwanted records from the shop schedule file, flag delays and roll the production history file forward.

Remove completed work - when work is completed by the shop according to the schedule prepared, the record associated with the part is not deleted from the schedule immediately but are only flagged. These have to be removed to the production history file. Any uncompleted work will also have to be flagged and their priority increased before rescheduling is done.

Production history file- each production history file record stores a 13 months' production history data. They represent the past 12 months

and current months' production of a particular stock item. The system date is reset every time after running the month-end processing program, so is the current month, which increases by one. Therefore, the past 12 months' production history records associated with each month is no longer correct and has to be updated. This is accomplished by rolling the production figures in the production history file forward by a month in order to reflect the month change.

Maintain work center utilization - the performance and utilization figures for each work center will be maintained for a 12 month period for management use.

As the files associated with the shop schedule and product history will be updated every time this program is run, the user will be asked,

HAVE ALL TRANSACTIONS FOR THE MONTH ENTERED. Y/N

Enter N if you are not sure and the program will exit. If you enter Y you will be again asked,

ARE YOU READY FOR MONTH-END PROCESSING. Y/N

Enter Y if ready or N to exit.

3. MANAGEMENT REPORT GENERATION

```
15-06-88        MANAGEMENT REPORT GENERATION          PROG:REPGEN

                    0. EXIT
                    1. PERFORMANCE MEASUREMENT REPORT
                    2. EXCEPTION REPORT
                    3. UTILIZATION REPORT

                                              CHOICE (0..3)
```

Figure A.39 Management Report Generation Menu

Enter the number of your choice for the report that you want to view on the screen or print it on the printer.

1.Performance measurement reports- this will present the plant productivity and the productivity of each work center in the plant.

2.Exception reports- this will display the parts that have a production cost much above the acceptable limit and also the delivery schedules completed during the month.

3. Utilization report- the work center utilization will be presented based on the capacity used and installed.

4. RANDOM INVENTORY COUNT GENERATION

```
15-06-88        RANDOM INVENTORY COUNT GENERATION        PROG:INVCOUNT

This program is designed to assist in physical counting of
high value items on a periodic basis.

This program will generate a random list of part numbers
to be checked based on user input. This will help reduce
pilferage, mis-handling of stock and in maintaining accurate
stock status in the data base.

     NO OF INVENTORY ITEMS IN THE MASTER FILE - 1878

     Please enter,

          1. Number of parts to be checked
          2. Base line cost for parts to be checked


     MAKE SURE THE PRINTER IS ON.  CHOOSE...Print/Quit
```

Figure A.40 Random Inventory Count Menu

The number of items in the file will be displayed and the user will have to input the number of parts to be checked and the least cost for the parts to be checked. Enter P to print or Q to exit program. Sample output is shown in Figure A.41.

15-06-88 RANDOM INVENTORY COUNT GENERATION Page #-1

Part #	Description	Qty. in file	Actual Qty.	Remarks
AHC02200	Assembly Hyd. Cylinder	18		
P1000010	Bronze bushing	400		

Figure A.41 Inventory Count Output

5. INITIAL SYSTEM DATA FILES SETUP

```
15-06-88        INITIAL SYSTEM DATA FILES SETUP        PROG:SETUP

This program should only be used to create the data files when
the system is initially installed. There will be eight new
files created on the diskette with the extension .DAT after
initialization.

The data files are :

          Workcenter file     - WORKCENT.DAT
          Routing index file  - RTINDEX .DAT
          Operations sequence - OPSEQ   .DAT
          Cost information    - COST    .DAT
          Production history  - PRODHIST.DAT
          Cost history        - COSTHIST.DAT
          Shop schedule file  - WORKLOAD.DAT
          Work center history - WORKHIST.DAT

  WARNING : RUNNING THIS PROGRAM WILL DESTROY ALL EXISTING
            CRP DATA FILES.


ARE YOU SURE YOU WANT TO DO THIS.                    Y/N
```

Figure A.42 Initial System File Setup Menu

The program should be used only to create the initial CRP database after the system is installed. Be certain that an empty diskette is placed in the data drive, otherwise all existing data files will be destroyed and new files initialized.

The following is a brief description of the data files.

1.**WORKCENT.DAT** - this file contains the details of the work center such as work center number, name, capacity, cost rates and efficiency.

2.**RTINDEX.DAT** - this index file points to the operation sequence records of a part in the operations sequence file. The stock number is used as the key for accessing a particular record. When searching for the operations sequence information this file is first scanned and the exact

location of the operations sequence is obtained. This breakup of the file permits for copying operations sequence information.

3.OPSEQ.DAT - this file contains the details of operations for a part such as operation number, name, work center number and operational time estimates.

4.COST.DAT - this file contains the direct material, direct labor and overhead cost information for every stock item.

5.PRODHIST.DAT - this file stores the past 12 months' production quantity for every stock item.

6.COSTHIST.DAT - this file stores the past 12 months' cost figures for every stock item.

7.WORKLOAD.DAT - this file is the shop schedule file that contains the part list for preparing a schedule. It stores the quantity and priority of parts.

8.WORKHIST.DAT - this file stores the past 12 months' work center performance information.

6. REORGANIZATION OF DATA FILES

15-06-88 REORGANIZATION OF DATA FILES PROG:REORGIND

When there are a large number of random insertions and deletions to the operations sequence file, the time required to access a particular record may increase significantly. Moreover, due to the organization of the file setup, for easy copying of information, random insertions will create orphans and these have to be deleted. This program is used to reorganize and rebuild the RTINDEX and OPSEQ files for more efficient handling.

Due to the limited amount of storage capability(360K) of a diskette after the reorganization, the rebuilt files will be written onto the diskette placed in drive A and the diskette in drive B will still contain the original data before reorganization. This is a safeguard even if the program is interrupted halfway, the original data file will remain intact and useful.

ARE YOU READY FOR REORGANIZATION. Y/N

Figure A.43 Data Reorganization Program Menu

After a large amount of random deletion/insertion of operations sequence information, the files will not be in any order and pointers have to be used to access the records. The time required to access a particular record may increase significantly. Moreover due to the file setup-primarily designed to permit copying information from one part to another, there may be records that have no links at all in the file and these have to be deleted. This program rebuilds the index and operations sequence in a logical and sequential manner.

Enter Y if you want to proceed or else enter N to exit the program.

7. CHAIN TO OTHER PROGRAMS

```
15-06-88          CHAIN TO OTHER PROGRAMS          PROG:CHAINING

This is a program provided in the current Capacity Requirements
Planning package for the user to use some other programs written
for accessing and manipulating the MRP/CRP data files.

The chain-to program should provide an option for the user to
return to the current CRP package, otherwise the user will have
to reboot the system to get back into the CRP package.

Please enter name(including path, if any) of the program to be
chained-to or an *  to exit.

    NAME OF CHAIN-TO PROGRAM :_
```

Figure A.44 Chain to Other Program Menu

This program provides a link from the CRP system data base to any other user-written routines. To run this program, remove the CRP diskette from the default drive and replace it with the other user-program diskette. Type in the name of the program to be chained to and hit <ENTER>.
If you are using a hard drive enter the complete path for the program. It is upto the user to incorporate the necessary chaining in his own program to return to the CRP package environment. Otherwise, you will have to bring up the CRP start up menu in order to return to the CRP software. The CRP data file structures are available at the end. This information is sufficient to enable a knowledgeable user to manipulate the CRP data file.

APPENDIX B

DATA RECORD FORMATS

WORKCENT.DAT 179

RTINDEX.DAT 179

OPSEQ.DAT 179

COST.DAT 180

PRODHIST.DAT 180

COSTHIST.DAT 181

WORKLOAD.DAT 182

WORKHIST.DAT 182

WORKCENT.DAT - stores the work center information.

Position	No. of bytes	Field description	Variable
01-03	3	Work center number	WCNUM$
04-28	25	Work center name	WCNAME$
29-31	3	Location code number	LOCN$
32-56	25	Work center description	WCDES$
57-60	4	Normal work center capacity	NCAP$
61-64	4	Max. work center capacity	MCAP$
65-68	4	Efficiency factor	EFFY$
69-72	4	Setup rate	SRATE$
73-76	4	Machine rate	MRATE$
77-80	4	Labor rate	LRATE$
81-84	4	Overhead rate	OHRATE$

Total - 84 bytes per record.

RTINDEX.DAT - routing information index file, points to OPSEQ.DAT file.

Position	No. of bytes	Field description	Variable
01-08	8	Part number index	PARTID$
09-10	2	Pointer to OPSEQ.DAT	RECPTR$

Total - 10 bytes per record.

OPSEQ.DAT - stores operations sequence information.

Position	No. of bytes	Field description	Variable
01-02	2	Operation number	OPNUM$
03-32	30	Operation name	OPNAME$
33-35	3	Workcenter number	WCN$

Position	No. of bytes	Field description	Variable
36-39	4	Setup time for operation	STIME$
40-43	4	Processing time for operation	PTIME$
44-46	3	Alternate work center number	AWCN$

Total = 46 bytes per record.

COST.DAT - stores product cost information.

Position	No. of bytes	Field description	Variable
01-04	4	Direct material cost	DMCOST$
05-08	4	Direct labor cost	DLCOST$
09-12	4	Direct overhead cost	DOHCOST$
13-16	4	Total cost	TCOST$
17-24	8	Unused field for expansion	NOCOST$

Total = 24 bytes per record.

PRODHIST.DAT - stores the monthly production quantities and production date(s) for a 13-month period.

Position	No. of bytes	Field description	Variable
01-06	6	Current month of last year	PH1$
07-12	6	Current month +1 of last year	PH2$
13-18	6	Current month +2 of last year	PH3$
19-24	6	Current month +3 of last year	PH4$
25-30	6	Current month +4 of last year	PH5$
31-36	6	Current month +5 of last year	PH6$
37-42	6	Current month +6 of last year	PH7$
43-48	6	Current month +7 of last year	PH8$

Position	No. of bytes	Field description	Variable
49-54	6	Current month +8 of last year	PH9$
55-60	6	Current month +9 of last year	PH10$
61-66	6	Current month +10 of last year	PH11$
67-72	6	Last month of current year	PH12$
73-78	6	Current month of current year	PH13$

Total = 78 bytes per record.

COSTHIST.DAT - stores the monthly cost information(direct material, and direct labor) for a 13-month period.

Position	No. of bytes	Field description	Variable
01-08	8	Current month of last year	CH1$
09-16	8	Current month +1 of last year	CH2$
17-24	8	Current month +2 of last year	CH3$
25-32	8	Current month +3 of last year	CH4$
33-40	8	Current month +4 of last year	CH5$
41-48	8	Current month +5 of last year	CH6$
49-56	8	Current month +6 of last year	CH7$
57-64	8	Current month +7 of last year	CH8$
65-72	8	Current month +8 of last year	CH9$
73-80	8	Current month +9 of last year	CH10$
81-88	8	Current month +10 of last year	CH11$
89-96	8	Last month of current year	CH12$
97-104	8	Current month of current year	CH13$

Total = 104 bytes per record.

WORKLOAD.DAT - stores the shop schedule information month.

Position	No. of bytes	Field description	Variable
01-08	8	Part number	PARTN$
09-38	30	Part description	PDESC$
39-40	2	Operation number	OPNO$
41-70	30	Operation name	OPDES$
71-73	3	Work center number	WCNO$
74-75	2	Production quantity	PQ$
76-76	1	Priority code	PRCODE$
77-78	2	Quantity produced	QP$
79-82	4	Time to produce quantity	TP$
83-86	4	Quantity remaining	QR$
87-90	4	Not used	NUSE$

Total = 90 bytes per record.

WORKHIST.DAT - stores the scheduled hours of every work center for a 13-month period.

Position	No. of bytes	Field description	Variable
01-04	4	Current month of last year	WS1$
04-08	4	Current month +1 of last year	WS2$
09-12	4	Current month +2 of last year	WS3$
13-16	4	Current month +3 of last year	WS4$
17-20	4	Current month +4 of last year	WS5$
21-24	4	Current month +5 of last year	WS6$
25-28	4	Current month +6 of last year	WS7$
29-32	4	Current month +7 of last year	WS8$

Position	No. of bytes	Field description	Variable
33-36	4	Current month +8 of last year	WS9$
37-40	4	Current month +9 of last year	WS10$
41-44	4	Current month +10 of last year	WS11$
45-48	4	Last month of current year	WS12$
49-52	4	Current month of current year	WS13$

Total = 52 bytes per record.